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THE ROLE OF AUTOMATION AND ROBOTICS IN ADVANCING UNITED STATES COMPETITIVENESS

ORIGINAL

mf 128

HEARING

BEFORE THE

SUBCOMMITTEE ON
SCIENCE, RESEARCH AND TECHNOLOGY

OF THE

COMMITTEE ON
SCIENCE AND TECHNOLOGY
HOUSE OF REPRESENTATIVES

NINETY-NINTH CONGRESS

FIRST SESSION

OCTOBER 7, 1985

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THE ROLE OF AUTOMATION AND ROBOTICS IN ADVANCING U.S. COMPETITIVENESS

MONDAY, OCTOBER 7, 1985

HOUSE OF REPRESENTATIVES,
COMMITTEE ON SCIENCE AND TECHNOLOGY,
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY,
Utica, NY.

The subcommittee met, pursuant to notice, at 9 a.m., State University of New York, College of Technology, Marcy Campus, Utica, NY, Hon. Doug Walgren presiding.

Present: Representatives Walgren and Boehlert.

Mr. WALGREN. Well, let me welcome you all here to these hearings.

I am Congressman Doug Walgren. I come from Pittsburgh, PA, and I am the chairman of the Subcommittee on Science, Research and Technology on the House of Representatives.

I want to say at the outset how pleased I am to be here in Utica with you, and how much I think of Mr. Boehlert, who is the ranking minority member of this subcommittee, and a driving force in the Committee on Science and Technology, for organizing these hearings and bringing us to Utica and to the Marcy Campus of the State University of New York.

These hearings on the role of automation and robotics in advancing our country's competitiveness are extremely important. All of us are aware that our manufacturing industries are in serious trouble, and that we, as a nation, have entered into a stage where we can be accurately described as a debtor nation, evidence that we are losing our share of the global manufacturing market.

The only way for American industries to compete competitively is obviously to continuously innovate, and robotics is of that process. Robotics technology will increasingly influence our lives, not only in what we do, but also in things that we no longer will do, and in that sense, this technology is capable of producing literally profound social change in our society. Millions of jobs will become obsolete, and technical retraining will become an absolute necessity for our population.

Last week, in Pittsburgh, we held hearings on a bill which both Congressman Boehlert and I have cosponsored, called the National Advanced Technician Training Act, which is an effort to focus on the retraining requirements that are going to be required by the rate of change which we must reasonably anticipate in our economic structure.

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Within the Congress, there has been a great deal of concern with the need to effectively use science and technology to increase our economic competitiveness. Last year, the Science and Technology Committee held a series of hearings on technological innovation, together with our counterpart in the Senate, passed in both the House and Senate, the Manufacturing, Science and Technology, Research and Development Act. The bill focused on trying to encourage the development and the use of robotics in the manufacturing sector.

We were disappointed that this law was vetoed by the President, but we also have to recognize that this is an area in which the country's future economy is going to go, and, so, although it may have been vetoed last year, we expect similar legislation to be passed eventually on the national level, and it will be the work of Mr. Boehlert and others who are particularly involved in the Science and Technology Committee, who are going to lead the way. Therefore, we appreciate your participating in this hearing, and giving us the benefit of your views on how we can best shape that kind of legislation.

This committee also has responsibility for authorizing the funding for robotics research at both the National Science Foundation and the National Bureau of Standards, which I understand has been particularly involved in your engineering studies here at Marcy. We want to know how those programs are working, and we want to be able to appreciate them so that we can extend that appreciation to others and do more of it.

With that for opening comments from me, I would like to recognize the ranking minority member of this subcommittee, who happens to represent this part of the country, and who you all know, I am sure, Congressman Boehlert.

[The prepared opening statement of Representative Walgren follows:]

OPENING REMARKS
OF
HONORABLE DOUG WALGREN (D-PA)
CHAIRMAN
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
HEARING ON
THE ROLE OF AUTOMATION AND ROBOTICS IN ADVANCING U.S. COMPETITIVENESS

I am very happy to be here in Utica this morning to join with my colleague, Mr. Boehlert, in holding hearings on "The Role of Automation and Robotics in Advancing U.S. Competitiveness.

I think all of us are aware that our manufacturing industries are in trouble. The fact that the United States' trade status has become that of a debtor nation, is evidence that we are losing our share of the global market in several manufacturing industries. The only way for American industries to compete effectively in the international market place is to innovate continuously, and robotics is part of that innovative process.

Robots, along with computer-aided design and machining, are beginning to affect the United States economy now. Robotics technology will increasingly influence our lives not only by the way in which we do things, but also by the things we will no longer have to do. This technology is capable of producing profound social change as well. Millions of jobs will become obsolete and technical job retraining will become a necessity. Last week, in my home territory of Pittsburgh, a hearing was held on the National Advanced Technician Training Act, which I introduced, and Mr. Boehlert co-sponsored, which is intended to help in the adjustments which will be required by this new technological revolution. The bill will create a matching grant program in the National Science Foundation to help community colleges develop model programs to train and retrain workers of all ages.

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Within the Congress there has been a great deal of concern with the need to effectively use science and technology to further our economic competitiveness. Last year the Science and Technology Committee held hearings on technological innovation, and together with the Senate Committee on Commerce, Science and Transportation, the two committees were instrumental in the passage of the Manufacturing Science and Technology Research and Development Act. The purpose of the Act was to restore American technological leadership and innovation in manufacturing through research and education activities, and to foster the development and use of robots and automated manufacturing systems. Unfortunately, the bill was veteoed by the President and never enacted into public law.

Also, The Science and Technology Committee has funded and monitored robotics research at both the National Bureau of Standards and the National Science Foundation through its annual authorization of both agencies. You will hear more about those programs directly from representatives of those agencies who are here this morning.

Technological innovation involves many factors and many players. I am looking forward to this opportunity to hear the views of industry, academia, and government in considering the role of automation and robotics in increasing productivity and competitiveness in this country.

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Mr. BOEHLERT. Thank you very much, Mr. Chairman.

Ladies and gentlemen, I would like to begin today's hearing by extending my thanks to Congressman Doug Walgren, who has served as chairman of the Science, Research and Technology Subcommittee for the last three sessions of Congress.

For the benefit of those unfamiliar with the subcommittee, let me preface my remarks by explaining that this subcommittee is responsible for authorizing programs and funding for the National Science Foundation, the National Bureau of Standards and several programs within the Department of Commerce, which enhance and promote the interaction between the Nation's scientific, research and engineering communities, both Federal and academic, and the industrial communities.

We, in the Congress, are very much aware of the decline of U.S. global industrial competitiveness and are concerned that the trade deficit keeps increasing. Our contact with numerous sectors of the economy indicates that a key to our regaining the leadership role in the world market is to be technologically innovative in automation of our industrial complex.

To this end, this subcommittee, through its authorization jurisdiction, is assisting in the process of educating the Congress, industry and academia in the importance of the cooperative effort necessary to win the technological/industrial race. The National Bureau of Standards has sponsored several programs with industry and academia to develop automation and robotics methods which can be adopted in U.S. industry.

One of these efforts is the automated manufacturing research facility being developed at the NBS to bring machine tools, robots and computer networks together in a simulated factory of the future. The object of this type of research is to replace extensive quality control efforts with integrated controls during manufacturing processing.

This example of NBS industry cooperation will, hopefully, seed future programs. The Bureau is sponsoring a Robotics Vision Research Program here at SUNY, College of Technology, and other similar programs at other universities.

Another example of Federal encouragement of automation is the establishment of six engineering research centers by the National Science Foundation to develop fundamental knowledge in engineering that will enhance U.S. industrial competitiveness. As a footnote, I might add that Chairman Walgren and I have been very instrumental in that program.

We have assembled here today a group of very distinguished individuals who are most familiar with the requirements for automation, the best direction to take in applying technology, and the curriculum required to properly educate the work force of the future. We welcome you and look forward to your testimony and guidance on this vital subject.

[The prepared opening statement of Representative Boehlert follows:]

OPENING STATEMENT OF HONORABLE SHERWOOD BOEHLERT (R-NY)
RANKING REPUBLICAN MEMBER
SUBCOMMITTEE ON SCIENCE, RESEARCH AND TECHNOLOGY
COMMITTEE ON SCIENCE AND TECHNOLOGY

OCTOBER 7, 1985

FIELD HEARING ON THE ROLE OF AUTOMATION AND ROBOTICS
IN U.S. COMPETITIVENESS

MR. CHAIRMAN, LADIES AND GENTLEMEN, I WOULD LIKE TO BEGIN TODAY'S HEARING BY EXTENDING MY THANKS TO MR. WALGREN, WHO HAS SERVED AS CHAIRMAN OF THE SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE FOR THE LAST THREE SESSIONS OF CONGRESS. FOR THE BENEFIT OF THOSE UNFAMILIAR WITH THIS SUBCOMMITTEE, LET ME PREFACE MY REMARKS BY EXPLAINING THAT THIS SUBCOMMITTEE IS RESPONSIBLE FOR AUTHORIZING PROGRAMS AND FUNDING FOR THE NATIONAL SCIENCE FOUNDATION AND THE NATIONAL BUREAU OF STANDARDS AND SEVERAL PROGRAMS WITHIN THE DEPARTMENT OF COMMERCE WHICH ENHANCE AND PROMOTE THE INTERACTION BETWEEN THIS NATION'S SCIENTIFIC RESEARCH AND ENGINEERING COMMUNITY (BOTH FEDERAL AND ACADEMIC) AND THE INDUSTRIAL COMMUNITY.

WE IN THE CONGRESS ARE VERY AWARE OF THE DECLINE OF U.S. GLOBAL INDUSTRIAL COMPETITIVENESS AND ARE CONCERNED THAT THE TRADE DEFICIT KEEPS INCREASING. OUR CONTACT WITH NUMEROUS SECTORS OF THE ECONOMY INDICATES THAT A KEY TO OUR REGAINING THE LEADERSHIP ROLE IN THE WORLD MARKET IS TO BE TECHNOLOGICALLY INNOVATIVE IN AUTOMATION OF OUR INDUSTRIAL COMPLEX. TO THIS END, THIS SUBCOMMITTEE, THROUGH ITS

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AUTHORIZATION JURISDICTIONS, IS ASSISTING IN THE PROCESS OF EDUCATING THE CONGRESS, INDUSTRY AND ACADEMIA IN THE IMPORTANCE OF THE COOPERATIVE EFFORT NECESSARY TO WIN THE TECHNOLOGICAL-INDUSTRIAL RACE.

THE NATIONAL BUREAU OF STANDARDS (NBS) HAS SPONSORED SEVERAL PROGRAMS WITH INDUSTRY AND ACADEMIA TO DEVELOP AUTOMATION AND ROBOTICS METHODS WHICH CAN BE ADOPTED IN U.S. INDUSTRY. ONE OF THESE EFFORTS IS THE AUTOMATED MANUFACTURING RESEARCH FACILITY (AMRF) BEING DEVELOPED AT THE NBS TO BRING MACHINE TOOLS, ROBOTS AND COMPUTER NETWORKS TOGETHER IN A SIMULATED "FACTORY OF THE FUTURE". THE OBJECT OF THIS TYPE OF RESEARCH IS TO REPLACE EXTENSIVE QUALITY CONTROL EFFORTS WITH INTEGRATED CONTROL DURING MANUFACTURING/PROCESSING. THIS EXAMPLE OF NBS-INDUSTRY COOPERATION WILL HOPEFULLY SEED FUTURE PROGRAMS. THE BUREAU IS SPONSORING A ROBOTICS-VISION RESEARCH PROGRAM HERE AT SUNY/UTICA AND OTHER SIMILAR PROGRAMS AT OTHER UNIVERSITIES. ANOTHER EXAMPLE OF FEDERAL ENCOURAGEMENT OF AUTOMATION IS THE ESTABLISHMENT OF SIX ENGINEERING RESEARCH CENTERS BY THE NATIONAL SCIENCE FOUNDATION TO DEVELOP FUNDAMENTAL KNOWLEDGE IN ENGINEERING THAT WILL ENHANCE U.S. INDUSTRIAL COMPETITIVENESS.

WE HAVE ASSEMBLED HERE TODAY A GROUP OF VERY DISTINGUISHED INDIVIDUALS WHO ARE MOST FAMILIAR WITH THE REQUIREMENTS FOR AUTOMATION, THE BEST DIRECTION TO TAKE IN APPLYING TECHNOLOGY AND THE CURRICULUM REQUIRED TO PROPERLY EDUCATE THE WORKFORCE OF THE FUTURE. WE WELCOME YOU AND LOOK FORWARD TO YOUR TESTIMONY AND GUIDANCE ON THIS VITAL SUBJECT.

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Mr. WALGREN. As you can sense, Congressman Boehlert and I work on this issue together. We feel that this is where the subcommittee ought to be, not necessarily in Washington, but moving around to localities where the work is actually being done, and, hopefully, to give you a more easy access to this kind of a hearing.

I am going to have to be relatively strict with the time this morning, and I apologize for that. I hope you understand that the Government is running out of money, and that means that although we will be able to pay for the transcript, there may be some dynamics in Washington later on in the afternoon that are going to require both Congressman Boehlert and myself to be there.

So, we are going to limit the witnesses to 10 minutes for their presentations. I would also like to say that that really works best because written statements will be reproduced as part of the record that is ultimately produced from these hearings. So, for those who study these records, particularly the staff of Members of Congress, both House and Senate, and those across the country who work from these presentations, your written statements will be there in all their fullness. This will allow you in your oral presentation to focus on those points that you really feel are the essential ones that deserve to be underscored. That will serve, I think, to enable other people to access these materials more directly if we have that kind of a focus in the verbal presentation.

So, with that, let me introduce our first witness. Why do I not let—Sherry, why do you not take over and start this thing off?

Mr. BOEHLERT. Well, I am particularly pleased to welcome Dr. Peter Cayan to his own campus. Dr. Cayan is president of the State University of New York, College of Technology, the very institution that we are privileged to be working from today.

Dr. Cayan.

STATEMENT OF DR. PETER J. CAYAN, PRESIDENT, STATE UNIVERSITY OF NEW YORK, COLLEGE OF TECHNOLOGY, MARCY CAMPUS, UTICA, NY

Dr. CAYAN. I think we need a bit of research to determine why tall people are always placed near the leg of the table. I am a little uncomfortable here playing games underneath the table.

Mr. WALGREN. I have always wondered why tall people were always the presidents of universities. I go back and I look, and in every instance, they have been at least 6 feet 4, and I think it has something to do with that we really do look up to folks in that capacity.

Dr. CAYAN. Congressman Boehlert, Chairman Walgren, committee members, colleagues and friends, thank you for your gracious invitation to appear before you this morning.

I believe that your presence on our beautiful campus is most noteworthy.

At the outset, I wish to solicit your indulgence that I might verbalize a brief connotation of the evolutionary significance of the State University of New York, more specifically, the College of Technology.

Some 22 years ago, I decided to attach my personal lot with State University of New York, and since that time, I have been privi-

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leged to have a ringside view of one of the truly exhilarating and creative periods in all of higher education.

The State University of New York is an imposing immense model. The very deliberateness of the structure and dispersions serves to publicly assert its intent to address the educational and cultural needs of the individuals.

In pursuit of this mission of teaching, research and public serve, the State University conducts advanced research in a variety of fields, sponsored by both governmental and nongovernmental agencies, to upgrade the quality of life and to improve health care services, thereby helping to solve the most urgent problems of our time.

University projects annually attract more than $153 million from Federal and State agencies, private foundations, industry and other sources, for research, training and related activities. A very considerable amount of research is conducted with State support and authorized research and for other departmental research.

I believe that nowhere is SUNY research initiative more apparent than in the university's partnership with business and industry. By collaborating with the private sector, SUNY has been contributing significantly to the economic development of New York State. Beginning with collaborative research, our industrial liaison program sustains on-going intellectual dialog between university researchers and their colleagues in the State's private firms and corporations. A process that often continues through patenting and licensing of new and improved projects.

State University of New York, College of Technology, Utica/Rome, is a specialized college in the SUNY system. As such, it is an upward division in graduate, master of science, institution awarding baccalaureate degrees in applied science, behaviorial science, business, computer science, the engineering technologies, nursing, social science, and now telecommunications.

Master programs in business and computer science complement the undergraduate offerings, and on that point, I would add that we are going to be moving very soon to add master programs in our other areas.

The college is organized to serve primarily the associate and applied science graduates in the State's 2-year public and private institutions. It operates on the premise that students transferring to the college of technology, in a parallel program, should be able to earn a baccalaureate degree in four semesters of full-time study.

Embryonic programs in pure and applied research help provide an invigorating environment for the college of professionally oriented students.

Since its inception, the college has strived to design programs which produce graduates who are conversant with the latest developments in his or her field. Our hope is that graduates so prepared can serve as catalysts and participate in the economic vitalization of the industry in which he or she is employed.

Since a number of our graduates go into the upstate New York employment market, we expect to have a major impact over time on the economy of this region in the long run. On that point, I would further add that this institution has sometime now established itself as not only an area college or institution, not even a State institution; we feel that our impact and our influence should

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go well beyond that and literally become an institution with regional relations.

The college of technology has been a leader among the SUNY units in industry education cooperation. It has for a number of years managed a small business institute, which furnishes consulting services to small business, those who are having financial difficulties, who are looking for ways to expand. This group has also provided services to local municipalities and developmental organizations.

The college follows up on a performance by regularly surveying employers of its graduates, to ascertain their satisfaction with the graduates' professional skills. In addition, we conduct extensive surveys in order to determine satisfaction of the general educational level of our graduates, and, in particular, in the telecommunications field of our graduates.

I might point out that response to date has been generally very favorable.

Surveys of all college of technology graduates are conducted 1 year after commencement, in order to study job placement and post-graduate activities, and we feel that this establishes a benchmark against which we can determine program quality, and rather than belabor the point, if one was to look at the variety of positions that our graduates take up, the amount or percentage of full-time employment that our graduates move into and the salaries, I think you will find them both impressive, and I would defer those statistics to the materials which you will have at hand.

As distinguished members of the Subcommittee on Science, Research and Technology, I believe that you constitute the hinge, that is the constituency connection. Our faculty, staff and students desperately need increased assurance that your influence with those many dimensions of off-campus relations will be judiciously applied.

Perhaps we are at a turning point of higher education, but grappling with new and difficult demands has been no stranger to us over the years. The unprecedented is not uncommon with the college of technology. The remedies we bring to the problems before us and the creative imaginations we apply to their solutions will help to determine that which lies ahead.

I, like you, view the future with anxiety, but also with an exciting confidence. If I might make a quick quote of Edward Cornish, who authored the Study of the Future:

> Since the future does not exist, it must be invented; and that is to say ideas about what might happen in the future must be generated and stated. Such ideas, or futuribility, are critically important because our thinking is shaped both by our concepts of what happened in the past and our images of what we may see in the future.

Yes, there are many things which need to be done, and although we may feel drawn onward, our colleges should be reviewing and refining operations within the context of a steady state. One might say that tomorrow will be a day like any other, times when there will be answers, and times with an over-abundance of those moments when you will feel like Erma Bombeck trying to cope, I guess, by getting from Monday to Friday in 12 days.

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I do not have any solutions, but I certainly admire the problem, quick glance at the headlines, not to mention the further content analysis, causes a sort of ambivalent sensation, that is excitement on the one hand and distress on the other.

For example, will robots bring more jobs or less (shift to high technology already pays dividends) from garbage collection to brain surgery with robots; high technology, blessing or curse; high technology, how big, what next?; high hopes for high technology; machines that think, they are brewing a revolution; and the impact of technology against society.

Increasing use of robots in the next decade will vastly improve the efficiency of American industry, but it could also displace, at least temporarily, hundreds of thousands of workers. During 1984, it was expected that from 8,700 to 15,000 robots would be used in this country. By 1990, experts say they could be doing a substantial amount of factory assembly work. Further statistics tell us that our industries will have in place 268,000 such machines with a predicted robot market of $5 billion.

On the more positive side, it is expected that many people will be replaced; however, the net effect will be additions to the work force as jobs in the care and feeding of robots are created.

And, when one extends his or her mental processes, the conclusion appears clear to me as a state of compromise. But what are the parameters of acceptable compromise? The evaluation of technology has amassed such momentum that it cannot be denied. The scope of advancement is so imposing that it commands our attention and action.

As you examine the collection of constituencies who have brought in to this phenomenon, the resulting complexity becomes evidence: labor unions, governments at all levels, corporate management, medicine, colleges and universities, and seemingly no end to the list.

The vested interests are so pervasive that only an approach predicated upon the absence of the emotions and the presence of reality can adequately embrace all concerned. We reside in a technological environment. The serious disparity which seems to be evolving is that of an awareness shortfall.

In fact, no matter how we individually or collectively relate to technology, it is obvious that the acquisition of some knowledge of our technological culture has become an imperative. For to begin to understand the essence of technology is to position one's self as being more capable of responding to change.

The fact is that we have been and are now going through a period of rather extensive social change and adjustment. Inasmuch as many of us find change difficult to accept or even fail to acknowledge its presence, we hasten to adopt strange notions as norms.

It is worth looking back at some published forecasts made in prior years to see the importance of correctly forecasting technological change. In 1907, W.W. Dean, president of the Dean Telephone Co., said, "You could put in this room," that was his office at the time, "all the radio telephone apparatus that the country will ever need." In the same year, Sir John Wolf-Barry of the Western Telegraph Co., said, "As far as I can judge, I do not look upon any

system of wireless telegraphy as a serious competitor with our cables. Some years ago, I said the same thing and nothing has since occurred to alter my views."

We do not hear much about either of those companies today, and it is not hard to guess why.

In 1935, Vice President Binkerd of the Baldwin Locomotive Co., said in a public speech, "In the future, our railroads will be no more dieselized than they are electrified." In 1938, President Dickerman of the American Locomotive Co., said, "Steam will continue to be the principal railroad motive power." By 1948, Baldwin had switched to manufacture of diesel locomotives, and American switched the following year. But it was too late for both. General Motors had already sewed up the market. Baldwin went out of business in 1956 and American in 1969.

For those who are familiar with American locomotives, the company was located in Schenectady, not too many miles from here.

I think a revealing anecdote, if you will, is in the 1920's, Dr. DeForest was shown a demonstration of how his work was being applied to the first operational black and white television. He went home that night and wrote, "While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility. A development which we need to waste little time dreaming about." And that came from the man who started the whole thing.

Past success sets the condition and becomes the necessary forerunner of future failure. I think that this is the most impressive statement I read in many a day, which has been provided to us by the great French philosopher and poet, Antoine deSaint-Exupery, once wrote, "When it comes to the future, the task is not to foresee it, but simple to enable it." And therein lies the challenge.

What will all this technological change mean in the end? For American industry, it will mean a renewed vitality for the contest with foreign rivals. For American labor, it will mean a painful adjustment for some workers and different opportunities requiring different skills for others.

For American society, if history is any guide, it will mean more challenging jobs, better products, and a cleaner environment, enhanced quality of life. On the other hand, I would be quick to urge each one of us to give particular attention to the author of "Technology By-products." "Illiteracy and its attendant condition of education disenfranchisement. Literacy today means more than being able to read, write and compute; the complexities of today and the future cannot be lightly dismissed." John Nynex, in his latest book, "Reinventing the Corporation," writes, "The late 1980's and 1990's will bring sizable labor shortages. The baby boom is being replaced by the baby bust which will create a seller's market in human capital. This enormous, yet largely unanticipated, shift will see companies in terrific competition for the best people."

In my opinion, gentlemen, the situation has all the makings of a catastrophic collision. That is, the confluence of the information has and the information have not.

Further, gentlemen, such goals are such that I think it will be lightning in a bottle. I also caution all of us to be suspect of those lorelei's of technology who have contracted a myopia which seems

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to preclude their accommodation of a more realistic position of compromise. High technology is not for everyone. The quality of anything, be it life or work or people, is never accidental. It is always a result of conscious effort, something which has been made to happen, and we dare not waste such an opportunity.

Our latest venture, which we feel is most exciting and relevant to today's needs and which serves to tie together all of our other activities, was the robotics electrical or computer, is the establishing of a telecommunications institute in cooperation with the Nynex Business Information Systems. Challenge and opportunity were apparent.

The challenge was to install a telecommunications system which would combine voice and data transmission. The system was required to handle voice, security, energy management and closed-circuit television. Further, it had to be expandable to cover additional buildings as they come on stream.

The opportunity was that the college would be an ideal setting for a living laboratory for such systems. Prototypes to be developed and tested while providing necessary services for the college of technology. The institution could support such a venture in a number of ways. It already had course work in the hardware domain, engineering technology; software in computer and information science; and in management of systems, business and engineering technology.

Faculty were doing applied research, in areas both directly and tangentially related to such a system. The operating system for the college's computing system is UNIX, in fact, the college holds the prototype license for UNIX in the SUNY system.

The new laboratory building included a rich antenna system for testing and developing a number of technologies. A vigorous continuing education division was positioned to man these seminars and to offer conferences and workshops, serving technical and management needs in a variety of industries.

Finally, the college as an emerging institution has had a great deal of latitude in focusing its considerable human resources to meet the needs of the partner in such a joint venture.

Well, the college has established a major telecommunications institute.

Is that the end of my time?

Mr. WALGREN. No; please finish.

Dr. CAYAN. A recent report by the board of trustees of the Carnegie Foundation for the advancement of teaching states:

> Today, the vital Federal connection to our colleges and universities is being challenged. After decades of strong bipartisan support, the current debate about budget priorities has been focused almost exclusively on numbers and on the negatives of higher education. The larger perspective has been lost.

We hear how much education costs, not how much it is worth. We are told that students are exploiters, rather than tomorrow's leaders. And we are reminded of the abuses, not the benefits of aid to higher education.

One is constrained to ask "Have we forgotten our history?"

We believe the Federal Government has a supporting role in our ventures. This college and the State of New York are contributing people, resources, and technology to the national scene. The compa-

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nies that hire our graduates are national and multinational, often with major commitments to defense. We want the Congress to see the SUNY College of Technology as a legitimate instrument of public policy capable of serving as a delivery system for quality education and applied research in the technologies.

Therefore, we ask you to give serious consideration to our desire to have the Federal Government join us as a partner for progress.

Thank you very much.

[The prepared statement of Dr. Cayan follows:]

STATEMENT OF DR. PETER J. CAYAN, PRESIDENT, STATE UNIVERSITY OF NEW YORK, COLLEGE OF TECHNOLOGY AT UTICA/ROME

Congressman Boehlert, Chairman Walgren, Committee Members, colleagues and friends.

Thank you for your gracious invitation to appear before you this morning. Your presence on our beautiful campus is most noteworthy.

At the outset, I wish to solicit your indulgence so that I might verbalize a brief condensation of the evolutionary significance of the State University of New York, and more specifically, the College of Technology.

Some twenty-two years ago, I decided to cast my lot with the State University of New York. And, since that time, I have been privileged to have a ringside view of one of the truly exhilarating and creative periods in all of higher education.

The State University of New York is an imposing and immense model. The very deliberateness of its structure and dispersion serves to publicly assert its intent to address the educational and cultural needs of the individual.

THE STATE UNIVERSITY SYSTEM

In pursuit of its mission of teaching, research and public service, the State University conducts advanced research in a variety of fields, sponsored by both governmental and non-governmental agencies, to upgrade the quality of life and to improve health care services, thereby helping to solve the most urgent problems of our time.

University projects annually attract more than $153 million from

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Federal and State agencies, private foundations, industry and other sources, for research, training, and related activities. A very considerable amount of research is conducted with State support in organized research and through regular departmental research.

SUNY's current research emphases include medicine and health care, dentistry, pharmaceuticals, biology, chemistry and biochemistry, and engineering, including computer science. These projects, many of them intercampus and multidisciplinary, deal with such diverse subjects as environmental problems and energy needs, transportation, space technology, industrial research and development, law enforcement, agriculture, health care delivery systems, natural resources, urban pollution, computer networks, nurse training, community development, and the needs of migrant workers.

Nowhere is SUNY's research initiative more apparent than in the University's partnership with business and industry. By collaborating with the private sector, SUNY has been contributing significantly to the economic development of New York. Beginning with collaborative research, our industrial liaison program sustains ongoing intellectual dialogue between University researchers and their colleagues in the State's private firms and corporations - a process that often continues through the patenting and licensing of new or improved products.

As a public university, SUNY has a special responsibility to make its resources in research, training/retraining, and technical assistance accessible to labor and local governments.

SUNY has established Public Service Offices throughout the University in order to match its resources with community needs.

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Training/retraining, part-time credit and non-credit programs were made available to more than 800 companies last year, for example, through SUNY's Development Centers for Business. Thirty DCBs have been created at SUNY to work with business and industry, helping them draw upon the University's varied resources.

COLLEGE OF TECHNOLOGY AT UTICA/ROME

The State University of New York, College of Technology at Utica/Rome is a specialized college within the SUNY System. As such, it is an upper-division and graduate (M.S.) institution awarding baccalaureate degrees in applied science, behavioral science, business, computer science, engineering technologies, nursing, social science, and now telecommunications. Master's programs in business and computer science complement the undergraduate offering. The College was organized to serve primarily the Associate in Applied Science graduates of the state's two-year institutions, both public and private. It operates on the premise that students transferring to the College of Technology in a parallel program should be able to earn a baccalaureate degree in four semesters of full-time study. Embryonic programs in pure and applied research help provide an invigorating environment for the College's professionally-oriented students.

Since its inception, the College has strived to design programs which would turn out graduates who are conversant with the latest developments in his/her field. Our hope is that graduates so prepared can serve as catalysts and participate in the economic vitalization of the industry in which he or she is employed. Since a number of our graduates enter the Upstate New York employment

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market, we expect to have a major impact over time on the economy of this region in the long run.

The College of Technology has been a leader among the SUNY units in industry, education cooperation. It has for a number of years run a Small Business Institute that provides consulting services to small business who are having financial difficulties or who are looking for ways to expand. This group has also provided services to local municipalities and developmental organizations.

The Business and Public Management Division runs its Advanced Management Program which is designed for middle managers in local business and industry. This program consists of ten short courses covering topics from finance to personnel to marketing.

Each degree program has an advisory board consisting of representatives from the industries who hire our graduates. They meet usually twice annually to review developments in the program, suggest needed changes, and offer guidance as the programs change to meet current needs in the marketplace.

The College follows up on our performance by regularly surveying employers of its graduates to ascertain their satisfaction with the graduate's professional skills. In addition, we survey satisfaction with the general education level of the graduate and, in particular, the oral and written communication skills of the graduate. Responses to date have been generally very favorable, and we have yet to find the employer who, having hired one of our graduates, is not willing to hire another as appropriate openings occur!

Surveys of all College of Technology graduates are conducted

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one year after commencement to study job placement and post-graduate activities. The most recent report (class of 1983) shows the following results:

Curriculum	Employed Full-Time	Graduate School Full-Time
Business/Public Management	91.3%	1.8%
Computer Science	88.7%	8.8%
Nursing	91.8%	4.1%
Health Services Management	76.8%	4.8%
Arts and Sciences	90.9%	0.0%
Technologies	97.8%	0.8%

A representative sampling of employee titles and companies is given below:

Position Title	Company
Information Systems Programmer	AT&T
Field Engineer	General Electric Ordinance
Maintenance Manager	Crown-Zellerbach
Associate Industrial Engineer	Grumman Aerospace
Engineering Analyst	General Electric
Vision System and Robotics	Norwich Pharmaceutical
Robotics	Carrier
Electrical Engineer	Par
Research Analyst	Oneida Silversmith
Nuclear Engineer	Niagara Mohawk
Electronics Communications Engineer	Harris Corp.
Senior Technical Aid	Sandia National Lab.

The faculty comes from all over the world. It is comprised of individuals who have a terminal degree, usually the doctorate, in their field along with industrial experience and interest in applied research. Current faculty research projects at the College include:

- o Operations research
- o Artificial intelligence
- o Simulation and modelling techniques
- o Axial flow compressors - jet engines
- o Radioactive measurement of tool wear
- o Human factors engineering
- o Robotics Intelligence
- o Robotics Vision
- o Micro processor, interfacing and controls

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As distinguished members of the Subcommittee on Science, Research, and Technology, you constitute the hinge; that is, the "constituency nnection." Our faculty, staff, and students desperately need increased assurance that your influence with those many dimensions of off-campus relations will be judiciously applied.

Perhaps we are at another turning point in higher education, but grapling with new and difficult demands has been no stranger to us over the years. The unprecedented is not uncommon with the College of Technology. The remedies we bring to the problems before us and the creative imagination we apply to their solutions will help to determine that which lies ahead.

I, like you, view the future with anxiety, but also with an exciting confidence.

Edward Cornish, author of The Study Of The Future, states that:

> "Since the future does not exist, it must be invented; that is to say, ideas about what may happen in the future must be generated and stated. Such ideas, or futuribility, are critically important because our thinking is shaped both by our concepts of what happened in the past and our images of what we may see in the future."

Yes, there are many things remaining to be done. And although we may feeldrawn onward, our colleges should be reviewing and refining operations within the context of a steady state. One might say that tomorrow will be a day like any other -- times when there will be answers and times with an over-abundance of those moments when you'll feel like Erma Bombeck, trying to cope by getting from Monday to Friday in 12 days.

I don't have many solutions -- but I certainly admire the problems.

A quick glance at headlines, not to mention any further content analysis, causes a sort of ambivalent sensation; that is, excitement on the one hand and distress on the other.

-will robots bring more jobs or less?
-shift to high tech already pays dividends.
-from garbage collection to brain surgery with robots.
-high tech, blessing or curse?
-high tech: how big? what next?
-high hopes for high tech.
-machines that think, they're brewing a revolution
-the road after 1984: the impact of technology on society.

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Will Robots Bring More Jobs or Less?

Increasing use of robots in the next decade will vastly improve the efficiency of American industry but it could also displace...at least temporarily..hundreds of thousands of workers. During 1984, it was expected that from 8,700 to 15,000 robots would be used in this country. By 1990 experts say they could be doing a substantial amount of factory assembly work. Further statistics tell us that our industries will have in place 268,000 such machines. On the more positive side, it is expected that many people will be "replaced," however, the net effect will be additions to the workforce as jobs in the "care and feeding of robots are created."

And when one extends his or her mental processes the conclusion appears clear to me as a state of compromise. But what are the parameters of acceptable compromise?

The evaluation of technology has amassed such momentum that it cannot be denied. The scope of advancement is so imposing that it commands our attention and action.

As you examine the collection of constituencies who have bought in to this phenomenon, the resulting complexity becomes evident: labor unions, governments at all levels, corporate management, medicine, the presidential candidates, colleges and universities, and seemingly no end to the list.

The vested interests are so pervasive that only an approach predicated upon the absence of emotion and the presence of reality can adequately embrace all concerns.

We reside in a technological environment. The serious disparity which seems to be evolving is that of an "Awareness Shortfall."

In fact, no matter how we individually or collectively relate to technology it is obvious that the acquisition of some knowledge of our technological culture has become an imperative. For to begin to understand the essence of technology is to position one's self as being more capable of responding to change.

The fact is that we have been, and are now, going through a period of rather extensive social change and adjustment.

Inasmuch as many of us find change difficult to accept, or even fail to acknowledge its presence, we hasten to adopt strange notions as norms.

It's worth taking a look at some published forecasts made in prior years, to see the importance of correctly forecasting technological change. In 1907, W.W. Dean, president of the Dean Telephone Company, said "You could put in this room (his office) all the radiotelephone apparatus that

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the country will ever need." In the same year, Sir John Wolf-Barry of the Western Telegraph Company said, "As far as I can judge, I do not look upon any system of wireless telegraphy as a serious competitor with our cables. Some years ago I said the same thing and nothing has since occurred to alter my views." We don't hear much about either of those companies today, and it's not hard to guess why.

In 1935 Vice President Binkerd of the Baldwin Locomotive Company said in a public speech, "In the future our railroads will be no more dieselized then they are electrified." In 1938, President Dickerman of the American Locomotive Company said, "Steam will continue to be the principal railroad motive power." By 1948, Baldwin had switched to manufacture of diesel locomotives, and American switched the following year. But it was too late for both: General Motors had already sewed up the market. Baldwin went out of business in 1956 and American in 1969.

In the 1920's, Dr. DeForest was shown a demonstration of how his work was being applied to the first operational black and white television. He went home that night and wrote: "While theoretically and technically television may be feasible, commercially and financially I consider it an impossibility.... A development which we need waste little time dreaming about." And that came from a man who started the whole thing.

Past success sets the condition and becomes the necessary forerunner of future failure.

The great French philosopher and poet, Antoine deSaint-Exupery, once wrote, "When it comes to the future, the task is not to foresee it but simply to enable it." And therein lies the challenge.

The tonic of high technology being administered to rejuvenate American industry is a bittersweet brew.

What will all this technological change mean in the end?

For American industry, it will mean a renewed vitality for the contest with foreign rivals. For American labor, it will mean a painful adjustment for some workers and different opportunities requiring different skills for others. For American society, if history is any guide, it will mean more challenging jobs, better products and a cleaner environment - an enhanced quality of life.

But, I also caution all of us to be suspect of those lorelei of technology who have contracted a myopia which seems to preclude their accommodation of a more realistic position of compromise. High Technology is not for everyone.

The quality of anything, be it life or work or people, is never accidental

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It is always the result of conscious effort --- something which has been made to happen. We dare not waste such an opportunity!

Our latest venture, which we feel is most exciting and relevant to today's needs and which serves to tie together all of our other activities, is the establishing of a Telecommunications Institute in cooperation with NYNEX Business Information Systems. challenge and an opportunity. The challenge was to install a telecommunications system which would combine voice and data transmission. The system was required to handle voice, security, energy management and closed circuit TV. Further, it had to be expandable to cover additional buildings as they come on stream.

The opportunity was that the College would be an ideal setting for a living laboratory for such systems. Prototypes could be developed and tested while providing necessary services for the College of Technology. The College could support such a venture in a number of ways. It already had course work in the hardware domain (engineering technology), software (computer and information science), and in management of systems (business and engineering technology). Faculty were doing applied research in areas both directly and tangentially related to such a system. The operating system for the College's computing system is UNIX - in fact, the College holds the prototype license for UNIX in the SUNY system. The new laboratory building included a rich antenna system for testing and developing a number of technologies. A vigorous continuing education division offered seminars, conferences and workshops serving technical and management needs

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of a variety of industries. Finally, the College, as an emerging institution, had a great deal of latitude in focusing its considerable human resources to meet the needs of a partner in such a joint venture.

The College has established a major Telecommunications Institute with an industrial partner - NYNEX Business Information System. Initially the Institute helped the College plan and purchase its own telecommunications system. This "state of the art" system provides for continual upgrade as well as expansion. Looking to the future, the Institute will sponsor credit and noncredit courses, workshops, specialized training, summer institutes and applied research. These will use the College's telecommunications system and draw upon existing faculty, curricula, equipment, and laboratories as well as augmented resources provided by the Institute. NYNEX is supplementing the College's efforts by providing equipment, planners, short-term faculty and an executive on loan.

In 1778, Thomas Jefferson drew up an education plan "To Raise The Mass of The People to The High Ground of Moral Respectability Necessary To Our Own Safety And To Orderly Government....."

A recent report by the Board of Trustees of The Carnegie Foundation For The Advancement Of Teaching States,

> "Today the vital federal connection to our colleges and universities is being challenged. After decades of strong bi-partisan support, the current debate about budget priorities has been focused almost exclusively on numbers and on the negatives of higher education. The larger per-

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spective has been lost.

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One is constrained to ask: Have we forgotten our history?"

We believe the Federal Government has a supporting role in our ventures. The College and the State of New York are contributing people, resources, and technology to the national scene. The companies that hire our graduates are national and multi-national, often with major commitments to defense. We want the Congress to see the SUNY College of Technology as a legitimate instrument of public policy capable of serving as a delivery system for quality education and applied research in the technologies. Therefore, we ask you to give serious consideration to our desire to have the Federal Government join us as a Partner for Progress.

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RESUME

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EDUCATION

B.S. - Economics - Siena College - 1959
Master of Business Administration - Siena College - 1964
M.S. - Education - State University of New York at Oneonta - 1967
Ed.D. - Higher Education Administration - State University of New York at Albany - 1975

Harvard University - Institute for Educational Management - 1978

EXPERIENCE

July 1982 to Present — **President, State University of New York College of Technology, Utica, New York 13502**

Chief executive officer of SUNY's newest specialized college offering career/professional curricula in engineering technologies, computer and information science, business/public management, health sciences and public services at the undergraduate and master's level. An upper level college enrolling 2200 FTE and employing 240 full-time faculty and staff. Currently presiding over the construction of a new $55 million campus.

September 1976 to June 1982 — **President, North Country Community College Saranac Lake, New York 12983**

Chief executive officer of a comprehensive community college enrolling 1200 FTE students, sponsored by Franklin and Essex Counties. Implemented a major campus building program; established three branch campuses and centers for study of the Adirondacks, gerontology, and crafts management.

December 1967 to August 1976 — **State University of New York Agricultural and Technical College, Delhi, New York 13753**

June 1975 to September 1976 — Dean of Non-Traditional Studies. Developed and maintained the A.A.S. degree and certificate programs in Individual Studies, as well as coordinated the college's extension/continuing education programs in central New York State.

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September 1970 to September 1976 — Dean, Division of Business Management. Coordinated academic programs in and administered four departments: accounting, business management, data processing, and secretarial science -- 20 faculty, two technical assistants, 500 students.

September 1967 to September 1970 — Department Head, Business Management. Promoted excellence in instruction and initiated recommendations for the development and improvement of curricula and courses.

December 1963 to September 1967 — Professor of Business Administration. Taught business organization, human relations, personnel administration, finance, supervision and economics.

November 1962 to December 1963 — **New York State Department of Labor**
Albany, New York

Statistician. Analyzed employment data for preparation of state and federal reports.

Personnel Technician. Recruited and evaluated qualifications of prospective candidates for state examinations.

June 1959 to November 1962 — **Albany International Corporation**
Albany, New York

Assistant Department Manager. Maintained production, quality control, personnel relations and safety.

Project Engineer (Personnel Administration and Industrial Engineering). Conducted time and methods studies for incentive plans and complemented special projects in personnel, job classification, and recruiting, as well as prepared materials for labor negotiations and interviewing.

September 1951 to June 1959 — **General Electric Company**
Schenectady, New York

Employee Relations Specialist. Investigated suggestions submitted by employees, conducted cost evaluations and prepared reports for management.

OTHER EDUCATIONAL ACTIVITIES

Member, Phi Delta Kappa.

Cornell University Managerial Process Analysis Program.

Administrative Consultant, Nursing Home Administration, Ithaca College. From 1968-1976 served as an adjunct member of the teaching staff.

Participated in an eight-week administrative training program at Albany Medical Center Hospital for the administrative operation of a medical center.

Supervisory Training Program for Food Service Personnel, State University of New York at Plattsburgh. Director of the Supervisory Training Program for training 70 food service personnel from various school districts in New York State.

Participated in a three-week institute at University of Iowa for training instructors to conduct short-term teacher education activities to improve their teaching.

Instructed corporation first-line supervisors and middle management personnel of the Champlain Valley Industrial Relations Council in the areas of administrative processes and performance review.
Program Development - Responsible for the initiation of the health services management degree program at SUNY Delhi.

Health and manpower consultant to the Regional Hospital Review and Planning Council of Northeastern New York.

Member, Organizing Committee: "The North Country Heritage Commission."

Member, Education Sub-Committee: Adirondack Park Association, Inc.

UNIVERSITY SERVICE

Chairman, Middle States Accreditation, Several Campus Visitation Teams.

Assistant Coordinator, School of Human Ecology, Cornell University, 1968-1976. Served as an adjunct member of the staff regarding the training of nursing home administrators.

Member of an advisory group in the School of Human Ecology, Cornell University for the development and implementation of workshops, seminars, and training institutes for personnel in health related fields.

Adjunct Professor, Cornell University, School of Industrial and Labor Relations.

Vice President, Two-Year College Council of Business Faculty Administrators.

Member, Association of Presidents of Public Community Colleges.

Member, State University of New York Task Force on Retention Improvement.

Presidents' Association Representative on the Faculty Council of Community Colleges.

Member, Chancellor's Council of Presidents, State University of New York.

American Association of State Colleges and Universities (AASCU). Member of Accreditation and Upper Level Colleges and Universities Committees.

PUBLICATIONS

Contributing Author. Text entitled NURSING HOME ADMINISTRATION, published by University Park Press.

"Future Directions/Community College Governance." ACCT TRUSTEE QUARTERLY, Summer 1980.

"Marketing Our Assets." ACCT TRUSTEE QUARTERLY, Fall 1983.

"Dubious Diversity--What Are Those Things Called Consortia?" A research paper presented before the American Association of State Colleges and Universities/Korean Council of University Education. Seoul, Korea (June 1984).

"The Disparity Factor -- He Sees, She Sees." A research paper to be presented at the World Conference on Cooperative Education, Edinburgh, Scotland (September 1985).

COMMUNITY SERVICE

Member, New York State Urban Development Corporation, High Technology Advisory Council.

Member, Board of Directors, Development Center for Business.

Member, Board of Directors, Industry, Labor, Education Council of the Mohawk Valley, Inc.

Member, Coordinating Committee of the Mohawk Valley Regional Education Center for Economic Development.

Member, Land of the Oneidas Executive Board, Boy Scouts of America.

Member, Board of Directors, Oneida County Industrial Corporation.

Member, Board of Managers, Faxton Hospital.

Member, Board of Directors, Medical and Surgical Care, Inc.

Member, Board of Directors, Mohawk Valley Applied Technology Center.

Member, Board of Directors, Chamber of Commerce of Greater Utica, Inc.

Member, Board of Directors, Arus Corporation.

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Member, Board of Directors, Mohawk Valley Executive Forum.

Trustee, College of Technology Foundation.

Vice Chairman, Allocations, United Arts Fund of the Mohawk Valley.

Past member, Board of Directors, Farmers National Bank, Saranac Lake, New York.

Past President, Saranac Lake Chapter, American Field Services.

Past member, Kiwanis Board of Directors, Lake Placid, New York.

Past member, Rotary International, Saranac Lake, New York.

Past treasurer, Board of Trustees, Educational TV, WCFE, Plattsburgh, New York.

Past First Vice President, Board of Directors, Chamber of Commerce, Saranac Lake, New York.

Past member, Board of Directors, Essex-Franklin Lyceum, Inc.

Past member, Board of Directors, North Country Community College Association, Inc.

Past member, Board of Directors, Center for Music, Drama and Art, Lake Placid, New York.

September 1985

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Mr. BOEHLERT. Thank you very much, Dr. Cayan. An outstanding and comprehensive statement. As we were reading over it, the chairman and I mentioned that fact to each other—how thorough it is—and I really appreciate it.

I just want you to know, No. 1 with your French philosopher, we agree with him, that we cannot foresee the future, but we are trying to enable it. That is extremely important.

Second, this committee particularly wants to be partners in progress with fine institutions like this. Third, I want to thank you for hosting at the college this hearing and I hope that you will be able to hear some of our expert witnesses that are going to follow.

Thank you very much, Dr. Cayan.

Dr. CAYAN. Thank you very much.

Mr. BOEHLERT. Our next witness this morning will be Dr. Nam Suh, Assistant Director for Engineering at the National Science Foundation, and who had to make that extra effort to be here.

Dr. Suh flew in this morning from Boston, he will have to leave immediately to go to New York City to give a major address and from there he is back to Washington.

Dr. Suh, it is good to see you again.

STATEMENT OF DR. NAM SUH, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION, WASHINGTON, DC

Dr. SUH. Good morning.

Mr. Chairman, Congressman Boehlert, and members of the committee, I appreciate the opportunity to speak to you about the automation and robotics. Getting outside the confines of Washington for a session such as this is refreshing and I believe it improves the environment for communication and discussion of the issues.

Automation and robotics can help America stay competitive. However, existing robots are too slow, too costly, and too limited in capability to be used effectively in many manufacturing processes. There are exceptions, such as the robot welding machines used by the automotive industry, but even these machines have limited "smarts".

Improvements have been made so that some of these machines use sensors to determine where the weld should be. But, we have a long way to go before robots will be able to perform the functions envisioned for them in the movie "Star Wars".

Another problem with existing automated systems and robots is that, while some can be reprogrammed, doing so takes such a long time that it is not cost effective in most small lot operations.

I know you are aware of many of these problems. I think it is generally recognized that the United States must have aggressive research programs in automation and robotics, if we are to retain our manufacturing industries in the face of growing international competition.

It is disturbing to me that so many U.S.-manufacturing firms have moved and/or are moving parts or all of their operations overseas. Manufacturing accounted for about 19 percent or approximately $700 billion of our $3.7 trillion GNP in 1984. It also accounted for 19.7 million jobs or 20.9 percent of the 94.4 million jobs

in the United States in that year. Manufacturing continues to be of critical importance to us.

As we examine the issues, I believe it is important to recognize that we are dealing with problems that involve much more than automation and robotics. We are being beaten, in some cases, because our foreign competitors, especially Japan, do a better job of design than we do. In other cases, we are behind in precision engineering. And, in others, it is a matter of quality control.

We must look at the problem of economic competitiveness as a system, and move on a number of fronts if we are to achieve our objective of maintaining international competitiveness.

To address this problem, in the past several months, the National Science Foundation has initiated three major programs aimed at the problems of design, manufacturing, and automation, with the view of helping U.S. industry to maintain its competitiveness over the long term. These are fundamental research programs. They will not produce results that can be used next year. But, they are laying the groundwork for what we hope will be a revolution in transferring human intelligence to machines, and in learning how to integrate the entire product development process from research concept to design, to manufacturing, distribution and marketing.

In April 1985, NSF awarded funds for the first six engineering research centers. These are major centers, located at universities, that will collaborate with industry on research that is focused on areas of technology of interest to industry. The idea is to mobilize the resources of universities and link university capabilities to the needs of industry. We believe that the ERCs will significantly enhance both engineering research and education.

Each center provides graduate and undergraduate engineering students with the opportunity to work as members of cross-disciplinary teams that are attacking various technology problems. This experience should better prepare students to be engineering practitioners. And, the results of the research should be of great value to industry. The centers also make equipment and instrumentation available for state-of-the-art engineering research.

The programs of one of the six centers are particularly germane to these hearings. The stated goal of the NSF-funded engineering research center at the University of California at Santa Barbara is: "to develop the fundamental engineering knowledge to design, build, and install robotic systems in microelectronics faster and more reliably than anyone else in the world."

The center's research program is focused on flexible automation for assembly and packaging, for materials transfer, and for process control. The cross-disciplinary research teams are moving in several areas, including robot design, digital motion control, assembly and packaging, color vision, advanced sending, and expert systems.

I will not attempt to describe all this work in detail, but some of the objectives are to develop systems that will monitor, diagnose, and correct failures in equipment for microelectronics manufacturing, to design and construct a high-precision robotic arm for operation in a clean room environment, to develop and construct a digital motion controller for high-precision positioning, and to develop robotic systems that will assemble and package microelectronic de-

vices. The research team at this center is headed by Dr. Susan Hackwood, formerly of Bell Laboratories.

We are coming to understand, as never before, that our competitors have placed a much higher priority on design and manufacturing technology than we have, at least in their engineering schools. Japan, for example, has, for many years, had a precision engineering specialty in each engineering school. Moreover, design and mechanical engineering have a high status in engineering in Japan. That has not been the case in the United States because these fields have not been viewed as being science-based.

We are trying to change the environment or the culture. Soon after I became Assistant Director for Engineering, we reorganized the engineering activity at NSF so that we now have a division that is focusing research on activities that will build a science base for design and manufacturing. This is a major departure from anything we have tried in engineering at NSF before. I had a lot of criticism at first, because people said we would not receive quality proposals in the design area.

Now that a year has passed, the record shows that the engineering community has many outstanding ideas in this area, and we are funding them. Actually, we received many more proposals than we can fund, which, I am sure, comes as no surprise to you.

We have a systems engineering research center at the University of Maryland in collaboration with Harvard University, and an engineering research center on intelligent manufacturing systems at Purdue University that, along with other engineering research centers, will contribute significantly to advances in robotics and automated systems.

Through research, we need to find ways to stay ahead in engineering and technology, and to give the United States a competitive edge. Revolutionary technologies are possible. The high cost and high risk prevent many of these embrionic technologies from becoming a reality. We need to explore ideas for bringing our institutional resources and our scientists and engineers together to work on these technologies.

Industry people have told us that they are eager to make such an effort, and I am sure that our universities and other research institutions would participate. There is great potential for us in this area, and we could reap benefits from such an effort in a relatively short time.

I believe that we must do a better job at working smart. By this I mean we must come out with new products and processes, and we must come up with creative and sound designs that are, to a large degree, foolproof in manufacturing and in usage. Studies show that, since the 1930's, research and development have been the most important contributors to improvements in productivity through the creation of high value added products.

As I mentioned earlier, we have much to accomplish in the area of automation and robotics. Even our most advanced commercial robots have difficulty in telling precisely where the end of their "hand" is at a particular time. They are primarily pick and place machines that are too slow to achieve major economies of scale in most operations.

As we move ahead with programs and thrusts in this general area, we should remember, too, that direct labor cost in manufacturing is an important factor, but not the most costly element. Overall, the average cost of direct labor for most products is about 5 to 15 percent of the total cost of production. However, we have to be cautious in using averages. You may be familiar with the story about the statistician who said that his boss had his head in the icebox and his feet in the oven but, on the average, he was feeling pretty good.

The point I want to stress is that we must look at automation and robotics in a broader sense than just trying to reduce labor costs. They have to reduce other cost elements as well, such as indirect costs. Also, automation and robotics may be the only way to improve the quality of certain products without increasing cost. The potential for productivity improvements that can be achieved through automation is enormous.

I believe that advances in automation and robotics, in the context of the broader parameters I have mentioned, are the only way to keep our manufacturing industries at home and, thus, keep our people employed in the years ahead.

As we look ahead, I believe we are going to need to expand opportunities for industry/university interaction and find ways for the Federal research laboratories to play a larger role in efforts to achieve and maintain United States competitiveness, both in high and mature technology fields.

The Engineering Research Centers [ERC] Program at NSF holds out real promise for breakthroughs in automation and robotics and many other fields as well, and our programs to build strength in design and manufacturing should help also. As you know, our Engineering Research Centers Program level is $25 million in the fiscal year 1986 budget. We are just getting that program started. There is much for us to do and, I believe, all Federal agencies with a research and development program should help in these efforts.

I am glad that the committee is focusing attention on this area. We cannot afford to take a back seat to anyone in automation and robotics. This completes my formal testimony, Mr. Chairman, Congressman Boehlert. I will be glad to answer any questions.

[The prepared statement of Dr. Suh follows:]

STATEMENT OF DR. NAM P. SUH, ASSISTANT DIRECTOR FOR ENGINEERING, NATIONAL SCIENCE FOUNDATION

AUTOMATION AND ROBOTICS

Mr. Chairman, Congressman Boehlert and members of the committee, I appreciate the opportunity to speak to you about automation and robotics. Getting outside the confines of Washington for a session such as this is refreshing, and I believe it improves the environment for communication and discussion of the issues.

Automation and robotics can help America stay competitive. However, existing robots are too slow, too costly, and too limited in capability to be used effectively in many manufacturing processes. There are exceptions, such as the robot welding machines used by the automotive industry but even these machines have limited "smarts"—that is, some weld every so many seconds at present sites whether there is a car there or not. Improvements have been made so that some of these machines use sensors to determine where the weld should go. But, we have a long way to go before robots will be able to perform the functions envisioned for them in the movie "Star Wars." We do not have a C3P0 or an R2D2. They both had intelligence.

Another problem with existing automated systems and robots is that, while some can be reprogrammed, doing so takes such a long time that it is not cost effective in most very small lot operations.

I know you are aware of many of these problems. I think it is generally recognized that the U.S. must have aggressive research programs in this area, if we are to retain our manufacturing industries in the face of growing international competition.

It is disturbing to me that so many U.S. manufacturing firms have moved and/or are moving part or all of their operations overseas. Manufacturing accounted for about 19%, or approximately $700 billion, of our 3.7 trillion dollar GNP in 1984. It also accounted for 19.7 million jobs, or 20.9% of the 94.4 million jobs in the U.S. in that year. Manufacturing continues to be of critical importance to us.

As we examine the issues, I believe it is important to recognize that we are dealing with problems that involve much more than automation and robotics. We are being beaten, in some cases, because our foreign competitors, especially Japan, do a better job of design than we do. In other cases, we are behind in precision engineering. And in others, it is a matter of quality control.

We must look at the problem of economic competitiveness as a system and move on a number of fronts if we are to achieve our objective of maintaining international competitiveness.

To address this problem, in the past several months NSF has initiated three major programs aimed at the problems of design, manufacturing, and automation, with the view of helping U.S. industry to maintain its competitiveness over the long term. These are fundamental research programs. They will not produce results that will be usable next year. But they are laying the groundwork for what we hope will be a revolution in transferring human intelligence to machines, and in learning how to integrate the entire product development process from research concept to design, to manufacturing, distribution, and marketing.

In April 1985, NSF awarded funds for the first six Engineering Research Centers. These are major Centers, located at universities, that will collaborate with industry on research that is focused on areas of technology of interest to industry. The idea is to mobilize the resources of universities, and link university capabilities to the needs of industry. We believe that the ERCs will significantly enhance both engineering research and education.

Each Center provides graduate and undergraduate students with the opportunity to work in cross-disciplinary teams as they attack various technology problems. This experience will better prepare students to be engineering practitioners. And the results of the research should be of great value to industry. The Centers also make available equipment and instrumentation for state-of-the-art engineering research.

The programs of one of the six centers are particularly germane to these hearings. The stated goal of the NSF-funded Engineering Research Center at the University of California at Santa Barbara is: "to develop the fundamental engineering knowledge to design, build, and install robotic systems in microelectronics faster and more reliably than anybody else in the world."

The Center's research program is focused on Flexible Automation for assembly and packaging, for materials transfer, and for process control. The cross-disciplinary research teams are moving in seven areas, including robot design, digital motion control, assembly and packaging, color vision, advanced sensing, and expert systems.

I will not attempt to describe all this work in detail, but some of the objectives are to develop systems that will monitor, diagnose, and correct failures in equipment for microelectronics manufacturing; to design and construct a high-precision robotic arm for operation in a clean room environment; to develop and construct a digital motion controller for high precision positioning; and to develop robotic systems that will assemble and package microelectronic devices. The research team at this center is headed by Dr. Susan Hackwood, formerly of Bell Laboratories.

We are coming to understand, as never before, that our competitors have placed a much higher priority on design and manufacturing technology than we have, at least in their engineering schools. Japan, for example, has, for many years, had a precision engineering specialty in each engineering school. Moreover, design and mechanical engineering have a high status in engineering in Japan. That has not been the case in the U.S., because these fields have not been viewed as being science-based.

We are trying to change the environment, or a culture. Soon after I became Assistant Director for Engineering, we reorganized the engineering activity at NSF so that we now have a Division that is focusing research on activities that will build a science base for design and manufacturing. This is a major departure from anything we have tried in engineering at NSF before. I had a lot of criticism at first, because

people said we would not receive quality proposals in the design area. Now that a year has passed, the record shows that the engineering community has many outstanding ideas in this area, and we are funding them. Actually, we received many more proposals than we can fund, which, I am sure, comes as no surprise to you.

We have a Systems Engineering Research Center at the University of Maryland in collaboration with Harvard University, and an Engineering Research Center on Intelligent Manufacturing Systems at Purdue University that, along with other Engineering Research Centers, will contribute significantly to advances in robotics and automated systems.

Through research, we need to find ways to stay ahead in engineering and technology, and to give the U.S. a competitive edge. Revolutionary technologies are possible. The high cost and high risk prevent many of these embrionic technologies from becoming a reality. We need to explore ideas for bringing our institutional resources, and our scientists and engineers together to work on these technologies. Industry people have told us that they are eager to make such an effort, and I am sure that our universities and other research institutions would participate. There is great potential for us in this area and we could reap benefits from such an effort in a relatively short time.

I believe that we must do a better job at "WORKING SMART". By that, I mean we must come out with new products and processes, and we must come up with creative and sound designs that are to a large degree foolproof in manufacturing and in usage. Studies show that, since the 1930's R&D has been the most important contributor to improvements in productivity through the development of high value added products.

As I mentioned earlier, we have much to accomplish in the area of automation and robotics. Even our most advanced commercial robots have difficulty in telling precisely where the end of their "hand" is at a particular time. They are primarily "PICK AND PLACE" machines that are too slow to achieve major economics of scale in most operations.

As we move ahead with programs and thrusts in this general area, we should remember, too, that direct labor cost in manufacturing is an important factor but not the most costly element. Overall, the average cost of direct labor for most products is about 5–15% of the total cost of production. However, we have to be cautious in using averages. You may be familiar with the story about the statistician who said that his boos had his head in the ice box and his feet in the oven, but, on the average, he was feeling pretty good.

The point I want to stress is that we must look at automation and robotics in a broader sense than just trying to reduce labor costs. They have to reduce other cost elements as well, such as indirect costs. Also automation and robotics may be the only way to improve the quality of certain products without increasing cost. The potential for productivity improvements that can be achieved through automation is enormous.

I believe that advances in automation and robotics, in the context of the broader perameters I have mentioned, are the only way to keep our manufacturing industries at home and, thus, keep our people employed in the years ahead.

As we look ahead, I believe we are coming to need to expand opportunities for industry/university interaction, and find ways for the Federal research laboratories to play a larger role in efforts to achieve and maintain U.S. competitiveness, both in high and mature technology fields.

The Engineering Research Centers program at NSF holds out real promise for breakthroughs in automation and robotics, and many other fields, and our programs to build strength in design and manufacturing should help. As you know, our Engineering Research Centers program level is 25 million dollars in the FY budget. We are just getting that program started. There is much for us to do and, I believe, all Federal agencies with an R&D program should help in these efforts.

I am glad that the Committee is focusing attention on this area. We cannot afford to take a back seat to anyone in automation and robotics. This completes my formal statement Mr. Chairman. I will be glad to answer any questions you or the other Committee members may have.

Mr. WALGREN. Thank you very much, Dr. Suh.

Let me ask if you would elaborate a little bit on that indirect cost business. You say labor is ranging in the 20-percent range or something like that. How can robotics really apply in the indirect cost areas? Could you give us some development of that thought?

Dr. SUH. Well, obviously, in manufacturing, in addition to people who operate machines and assemble products, we always have large numbers of people who support the system through paper work and so forth. Many of these activities can be simplified and computerized when can exactly the same operating occurs over and over again.

When you do not have automation, when you depend on individual operators, then you cannot rely on what those people will do and, therefore, automation of the paper work, with all the information processing part of the manufacturing, becomes rather difficult.

However, automating the manufacturing operations enables us to automate the information processing end of the manufacturing operations and that greatly reduces indirect labor costs.

In fact, if we look at how manufacturing costs are divided up, materials costs turn out to be one of the major items and next are indirect costs. Materials costs, if you define materials costs as being all the costs associated with buying components and machine elements that a factory purchases, can be anywhere from 50 to 75 percent of the costs. Each direct labor cost can be anywhere from 20 to 30 or 40 percent, depending on the operation. Then there are the labor and capital costs, too.

So, by being able to automate, I think it is every one's belief that indirect costs can be reduced. That should effect savings and help us to be more competitive. In fact, it is amazing how high overhead costs are in these operations.

Mr. WALGREN. Now, let me ask one other question.

We understand that the National Science Foundation has largely focused on funding the lead edge of the research, and certainly your engineering centers are driven in that direction by budget and by purpose.

But what can you tell us about the support for undergraduate engineering instructional development? When we think of this problem of competitiveness as requiring a very broad-based attack and putting these pieces together, are we able to do anything presently through the National Science Foundation focused on undergraduate instructional development in engineering as a sort of a more broad-based focus?

Dr. SUH. Well, Mr. Chairman, I think that is a very relevant and very urgent issue that you are raising. We have been very concerned about that very issue for the following reasons: unlike the pure sciences, in engineering, the bachelor of science degrees in engineering, masters of science degrees in engineering, and Ph.D. degrees, in engineering are regarded as terminal degrees.

In fact, 78 percent of engineers in U.S. industry hold only baccalaureate degrees or less, and more than 50 percent of the engineering graduates are coming out of institutions that do not receive any support from the National Science Foundation. Yet, these are the people who man our engineering enterprises. We believe that, we need to put greater emphasis on supporting some of these institutions in order to deal with this. We have a large number of initiatives that are being considered. Some are already being implemented.

One of these programs is called the University/Industry Government Partnership for Quality Engineering Personnel. The idea is to

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enhance continuing engineering education by bringing the best brains, the best experts in industry into engineering classrooms.

The idea is not to have them abandon their industrial jobs and come into the classrooms, but rather to have them collaborate with professors on campus in developing course content. Then, after helping in this way to strengthen engineering instruction in classrooms, we would like to have industry engineers who are actually designing machines and making products give lectures from their own sites illustrating how they do these things. They would show what they have done and then transmit the information using satellites into the classroom.

This is one of the new initiatives we are undertaking. We are excited about its chances for success. It has the potential to change the makeup of engineering education. By actually enlisting the help and using the resources that are at work in industry in the education process, the relationship between universities and industries can be strengthened in a significant way.

Obviously, this is only one element in our program. There are many other things that we want to do, especially to bring more women and minorities into engineering because we really need to have the best brains we have in the country to serve as engineers in industry and other institutions.

As you know, the number of 18-year-olds is going to drop dramatically in the next few years, and, therefore, it is very important and imperative that we attract additional brain power to engineering from sources now under represented in engineering.

We are not doing enough in this area in my opinion. We are continuing to hold a large number of workshops and so forth in our effort to find ways for NSF to make more effective efforts that will attract women and minorities to engineering.

This is a new test for the National Science Foundation, because in the past, NSF has only concerned itself with the production of research and Ph.D. level scientists. The reason for that is in pure science, only Ph.D.'s are regarded as the practitioners of the profession. By contrast, in engineering, the baccalaureate degree is a professional degree. Yet, at NSF we have concentrated on the Ph.D. and it has dominated our thinking. I believe it has a bias toward Ph.D. programs. We need them but we need other things too if engineering is to be made strong.

Mr. WALGREN. Thank you.

Mr. BOEHLERT. Dr. Suh, you know, whenever there is a discussion of robotics and automation, automatically a dark cloud sort of hovers over the discussion in the minds of the general populus because of the social implications, the displacement of workers, that sort of thing.

But as you pointed out so well when you gave us your statement, we have no choice, and our competitors in the global market place are working smarter than we are, and that is one of the reasons we have a decline in the manufacturing sector.

How would you compare where we are right now versus our major competitors in the international market place? Japan, particularly, comes to mind.

Dr. SUH. Well, certainly, when we visit Japanese factors, we find that they are using more robots in their manufacturing operations.

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Indeed, the number of robots installed in Japan exceeds that of any other country in the world. They use very simple robots and also very complicated ones. Certain tasks can be done with very simple robots and certain tasks can be done only with very complex robots.

Indeed, the Japanese are aggressive in this area. When I was heading up the Center for Manufacturing at MIT, the Japanese firms were the only ones sponsoring research at MIT in the robotics area. We tried to get American firms to sponsor research on robotics, but we could not get any support from them.

So, finally, in desperation, after trying for 1½ years, we got the support of our industrial advisory committee. They encouraged us to go and seek Japanese support. So, we started writing letters to Japan. In a matter of months, we had four Japanese companies giving us a quarter of a million dollars or more to do research in the robotics area.

The displacement of workers and so forth may be a consequence of automation. However, I expect there were similar concerns when farming was mechanized. I think the first thing we have to consider is how to make sure that the overall wealth of the United States increases so that every one in the country benefits. Then, hopefully, that increased wealth will be distributed in such a manner that everybody will benefit by the value added through automated manufacturing processes.

However, I have a feeling that, if we make use of revolutionary technology that can change the makeup of industrial technology in a dramatic way, as I testified earlier, then perhaps we can create new jobs as well. In fact, in some ways, I have a feeling that we are very timid. We seem to think only about automating the things we have been doing today rather than asking ourselves how we can surpass other nations in manufacturing areas. That requires that we find ways to do things that our competitors have not even conceived of doing. At this stage, I believe this is possible.

There are many, many creative people. In fact, there are large numbers of firms in the United States with very interesting technologies. But, each firm and each university cannot take advantage of these technologies. They do not have the resources to undertake the major efforts needed to bring about the commercialization of these embrionic technologies.

I have a feeling that we ought to concentrate in some of these areas. Even with automation, we create new jobs because we create new technologies. Trying to hold on to the same jobs that people have had for decades may not be the winning formula for us.

Mr. BOEHLERT. So, if we proceed as you would envision then, as we should, you can foresee a greater number of job opportunities rather than a lesser number of job opportunities?

Dr. SUH. Well, that is my perception of the situation. Indeed, by trying to hold onto the jobs that we used to have, in fact, we end up eroding our industrial base. I think that has got to change. We ought to increase our industrial base by creating new technologies, new job opportunities, and then I think the task of——

Mr. BOEHLERT. Doctor, you find the acceptance of that in the universities and our college campuses. Do you find that same acceptance in the industrial sector?

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Dr. SUH. Well, Congressman Boehlert, I had a very interesting meeting and lunch with a representative of one of the larger corporations in the United States. By the way, I took him to lunch. So, do not worry about it.

It turns out that they have a technology that they think would change the way we make automotive parts, aircraft parts, and all kinds of things in a very dramatic way.

After listening to him, I tended to agree with him that we can change the way we make things in a very, very dramatic way. But, the reason he came by to see me was to tell me that his company alone cannot bring that technology to fruition. Even though it is a very large corporation, it cannot reduce the technology to commercial viability because it does not have the diversity of expertise and resources required to do it alone. There is a great deal of risk involved in such undertakings.

However, he feels that, if we can work together, his company and the universities and other companies, with some encouragement from the National Science Foundation, we can bring it about. Such a combined effort could give us a dramatic lead in engineering in the future.

Mr. BOEHLERT. The encouragement can be in the form of dollars?

Dr. SUH. I guess that is often what it means. However, I have a feeling that and obviously he is going to be coming back to me with some details on what his company is doing. If his company were to put in $10 million, and we could put in $10 million as well, we could work it out. Whether or not his top management will agree with that, who knows. But, these are the possibilities.

I think we really ought to look at these very revolutionary technologies that can dramatically change the way we do things. That is the only way we can really be competitive in the years to come.

Mr. BOEHLERT. Excuse me. One last question, Dr. Suh.

So often, when the NSF activities are reviewed, I think there is a perception that you are kind and generous to the major institutions, the name institutions, the established institutions, but there is some concern that the newcomers, and this very campus, I would put in that category, do not have much opportunity to share in some of the disbursements from NSF.

Can you give some encouragement to a place like the college of technology that you would be receptive, and can you give some indication if that, in fact, is taking place in terms of funding for activities on the smaller emerging institutions like this one?

Dr. SUH. Well, we are, first of all, very concerned and sensitive about this issue. We are concerned, because this perception may not be true, and, yet, the perception prevails.

For example, when we set up the six engineering research centers, three of these engineering research centers were established at institutions that did not get much NSF support in the past. In fact, the University of California at Santa Barbara did not get much NSF support at all. That institution had hired three people from Bell Laboratories and started this effort, and NSF gave them one of the ERC awards.

And, you can say the same thing about the University of Maryland. It was not a major recipient of NSF money in the past, and the same is true for the University of Delaware. So, first of all,

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NSF resources are available to any one who comes our way with good research ideas. We are looking for ideas. We are not there to simply support every engineering department in every engineering school, because, as you know, our budget is small.

On the other hand, I also believe that part of the perception on this issue stems from the fact that, instead of looking at the number of faculty members different schools have in engineering, the critics look at each school as an entity.

For example, if you take MIT, they have something like 400 staff members in engineering, and they have over 800 or 900 staff members in science and engineering together. By comparison, other schools have much smaller staff.

So, you can imagine that the success ratio will be proportional to the number of staff members who write proposals to us. However, I also feel that what you are saying is true, that people from less known institutions have disadvantages in that, sometimes, the recognized names often have advantages over those who are just trying to start a new program.

We are aware of this. In fact, I have told all my program directors that at least 10 percent of the budget has to be used for new researchers, researchers who have not received any money from NSF during the past 3 years. I believe this is a step in the right direction.

We need to look at these things and another thing too. I would like to note that we have some special programs designed for the institutions that do not have large graduate programs. One of these is the Predominantly Undergraduate Institution Programs. Under that, program, engineering paid out more than $5 million in 1985. We intend to increase that. I think that we need to give more support to institutions of this type.

The problem I have in this area is that we have not not received enough good quality proposals. So we have had difficulties meeting the target that we have established within the National Science Foundation total.

But, I think, really, the thing that I would like to ask my colleagues in the university community to do is to call us, to talk to us, to come to see us. We can work with them and help them to bolster their programs so that they can get a large share of NSF resources.

Mr. BOEHLERT. I try to do it one better. I have an ulterior motive, and one of the reasons we are having this hearing here is so that I can help a less known institution become better known, and I thought it would be easier on SUNY College of Technology's budget to bring Washington to Marcy rather than the other way around.

Dr. SUH. Thanks to your kind efforts, I had the pleasure of meeting the president of Utica College and also the dean of engineering at Syracuse. We had a very interesting discussion. They are coming down to NSF within the month to discuss a number of different avenues available for their participation in carrying out research and education in engineering.

Mr. BOEHLERT. We tried to make that arrangement for that meeting, and, Doctor, I know you have a plane to catch to get down to New York City for another speech and then back to Washington.

I want to thank you very much on behalf of the subcommittee for your testimony, and if you will leave your statement for the record, I would appreciate that.

Dr. SUH. Fine. Thank you very much.

Mr. WALGREN. Thank you, Dr. Suh.

Our next witnesses are Dr. Frederick Diamond, the Chief Scientist at the Rome Air Development Center, with the U.S. Air Force here at Rome, NY. If you gentlemen would come forward, and let me again at the outset indicate that we are shooting for a 10-minute period, and we will take you in the order that we called you, one after the other, hopefully leaving a little time for some discussion after you have completed your presentations. Written statements will be made a part of the record automatically, and please feel free to summarize or focus and outline those parts that you feel you most want to underscore.

Dr. Lyons.

STATEMENT OF DR. JOHN LYONS, DIRECTOR, NATIONAL ENGINEERING LAB, NATIONAL BUREAU OF STANDARDS, GAITHERSBURG, MD, ACCOMPANIED BY MR. SAM KRAMER, DEPUTY DIRECTOR, NATIONAL ENGINEERING LAB

Mr. LYONS. Thank you, Mr. Chairman.

Thank you for providing an opportunity for the Bureau of Standards to discuss its work in automation of manufacturing processes.

I would point out, Mr. Chairman, that Mr. Kramer, our Deputy Director, does not have a formal statement. So, he will be available to answer questions.

The National Engineering Laboratory of the Bureau conducts a variety of programs in measurement methods, calibrations, reference data and materials, proposals for standards and codes and new engineering practices; providing the generic technology that enables industry to produce specific products and process developments.

The laboratory's major efforts are in electronics, electrical engineering, chemical engineering, building and fire research, applied mathematics, and manufacturing engineering, and it is to the last named area that we plan to address the remainder of our remarks.

The Bureau has, since its inception, provided to industry techniques to make proper measurements of length. For the machinist, this service has, until recently, come in the form of gauge blocks, rectangular chunks of steel of certified length. The machinist uses these blocks to set the zero on the micrometer used to measure the work piece. NBS calibrates and certifies sets of these gauge blocks, thereby assuring that every machinist is measuring against the same standard.

In recent years, automated machining and gauging have entered the scene. Three-dimensional coordinate measuring machines are replacing the micrometers. We had to learn a great deal about the coordinate measuring machines, including how to correct errors from distortion.

We decided to move this new correction technology along to the correction of machine tools themselves, and thus we came logically to the current NBS program in automated manufacturing.

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The program has two major components: devising the measurement technology for the fully automated factory, and providing the necessary technology for interface standards to facilitate communications among the many computer-controlled devices in such a factory. The NBS automated manufacturing research facility, or AMRF, is the test bed for this activity.

There are at least two ways to provide the new measurement techniques: first, very fast or real time measurements of the work piece, and, second, sensing of the conditions of the machines themselves followed by real time corrections according to models of the machine behavior so that the machines remain within the prescribed limits.

Both approaches require advance work on sensors as well as on controls. Robots may be considered as machine tools. We often need to know just where the end effector of a robot is as well as the forces on it and what objects are within its working volume. This means a variety of sensors, including robot vision. We are addressing these problems and testing some new concepts on the AMRF.

We use the AMRF to evaluate new ideas for control of the factory, including the computer interfaces. The AMRF consists of five work stations, each having a machine tool and a robot server. There is a hierarchy of controls, a central data base and mail box, and a communications network.

We have deliberately purchased or received on loan machines from as many different manufacturers as possible so that the number of interfaces among unlike devices is maximized.

We have developed a concept of neutral data formats such that all the disparate devices can communicate with each other. The approach allows construction of a modular factory in which each device retains its proprietary nature and advantages.

The AMRF will be fully operational by the end of the fiscal year 1986. We will then enter a period of research using the full system. We are this month holding a workshop to see if industry has a set of research problems that might also be addressed using the AMRF. We plan to make the facility available to industry for such work. The AMRF has attracted both support and collaborators. We presently have 14 industrial research associates, loans or donations of equipment from industry totaling $3.3 million, grants to 14 universities and collaborations with 22.

We have a grant with the SUNY College of Technology on the subject of robot vision. The U.S. Navy is a major sponsor. So, the AMRF is a good example of close collaboration of the type all of us believe is a healthy and effective use of scarce resources.

We have been engaged in this program long enough to draw some conclusions that are pertinent to this hearing. It is my belief that technology will not be limiting. Given the staff, funds, and equipment, we can devise a technical response to just about any problem in automation that may arise on the factory floor.

There will be a very large store of new technology accumulating over the next decade. The challenge is to take advantage of all this new knowledge in our production facilities, for only by putting the technology to use will there be an effect on our industrial competitiveness.

There are two barriers. One is the slow pace of investment in the technology; the other is the relative scarcity of trained personnel to install and operate fully automated factories.

Management remains reluctant, probably for reasons grounded in tradition, inertia, and fear of the unknown, for adopting new technology involves a fair amount of risk.

The second barrier is a lack of highly skilled personnel. The factory of the future will require technically sophisticated staffing. The factory of the future will not be unmanned. Most of the time it will be supported by staff who must be intimately familiar with the operation of the computer-controlled machinery, able to program changes in design, capable of dealing with computerized data bases, interfaces and the like, from the operating point of view.

They will have to work with automatic feedback loops, robot technology and advanced systems concepts. Such staff must also acquire the intuitive feel for the process that in the past has come from long association with machines and their eccentricities. This characteristic is what we now have in master machinists and tool and die makers. Such people are increasingly in short supply and, in general, do not have the computer skills that will be needed in the future. So, one assignment for our educational system is to help upgrade the craftsmen we now have through intensive continuing education programs. This is not retraining because we want to preserve their existing know-how and graft on to it the new skills.

We will need a great many new engineers. Engineering technology programs can provide a great many of these people. The level of technical familiarity which an engineering technologist would appear to be very well suited to the needs on the floor.

As Gordon Millar, a retired vice president of Deere & Co., has put it recently, engineering technology is "a new profession all its own that is based on the application of engineering principles to the physical operation of highly complex, computer-integrated manufacturing activities."

I believe the SUNY College of Technology here at Utica can be a source of these highly prized factory engineers, and I encourage the college to enhance the program in this direction.

In summary, the technology of factory automation is coming and coming fast, driven by the continuing explosive revolution in computer technology. For the Nation to reap the benefits in improved competitiveness that this technology surely offers, top management must make the necessary financial commitments and our educational system must supply the technically skilled personnel.

Colleges and universities clearly have a key role to play both in doing research in factory automation and in educating a large number of technologists.

Thank you, Mr. Chairman. Mr. Kramer and I will be pleased to answer any questions the subcommittee may have.

Mr. WALGREN. Thank you very much, Dr. Lyons.

Let us turn to Dr. Diamond.

[The prepared statement of Dr. Lyons follows:]

U S Department of Commerce
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Statement of

John W Lyons, Director

National Engineering Laboratory
National Bureau of Standards

before the

House Committee on Science and Technology
Subcommittee on Science Research and Technology
on
Automation and Manufacturing

Mr Chairman, thank you for providing an opportunity to the National Bureau of Standards (NBS) to discuss its work in automation of manufacturing processes. Mr. Samuel Kramer, Deputy Director of the National Engineering Laboratory (NEL) is also a witness; however, he does not have a formal statement. Both of us will be pleased to answer your questions following my formal remarks.

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The National Engineering Laboratory of the National Bureau of Standards conducts a variety of programs which provide to industry, academe, and other government groups the following technical services: measurement methods, calibrations, reference data and materials, proposals for standards and codes of many kinds, and new engineering practices. We operate generally in the early research stages of the innovation process providing the generic technology that enables industry to do specific product and process development. Some have termed this supporting technolgy "infratechnology" because to many it lies below and provides the foundation for the more visible work of industry. The National Engineering Laboratory has major efforts in electronics and electrical engineering, chemical engineering, building research, fire research, applied mathematics, and manufacturing engineering. It is to the last-named area that we plan to address the remainder of our remarks.

The program in manufacturing engineering includes the NBS work in dimensional measurements. The Bureau has since its inception provided to industry techniques to make proper measurements of length. For the machinist, this service has until recently come in the form of gage blocks -

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rectangular chunks of steel of certified length. The machinist uses these blocks to set the zero on the micrometer used to measure the work piece. NBS calibrates and certifies sets of these gage blocks to this day, thereby assuring that every machinist is measuring against the same standard.

In recent years this approach has become less useful as automated machining and gaging have entered the scene. Three-dimensional coordinate measuring machines (CMM"s), devices capable of gaging complex parts under computer control, are replacing the micrometer. In order to provide services for these machines we had to learn a great deal about CMM's including how to correct errors from distortions so as to enhance the accuracy of the machines. Once we learned to do this and provided the necessary measurement services we decided to move the technology along to the correction of machine tools themselves. Thus we came logically to the current NBS program in automated manufacturing.

The program has two major components: devising the measurment technology for the fully automated factory of the future, and providing the necessary technology for interface standards to facilitate communications among the many computer-controlled devices in such a factory. Along

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the way we find we must develop a number of associated concepts and have a way to test them in a realistic environment. The NBS Automated Manufacturing Research Facility (AMRF) is this test bed .

There are at least two ways to provide the new measurement techniques: (1) very fast (real time) measurements of the work piece as it is being processed with real-time feedback to the machine controls so that tool corrections are made essentially instantaneously, and (2) sensing of the machines themselves followed by real-time corrections according to models of the machine behavior so that the machines remain within prescribed limits. Both approaches are being studied although we lean to the latter method as a natural follow-on to the work we've already done on error correction for CMM's and individual machine tools. Both approaches require advanced work on sensors as well as on controls. For the purpose of this discussion the robots used in such a factory may be considered as machine tools. We often need to know just where the end effector of a robot is as well as the forces on it and what objects are within its working volume. This means a variety of sensors including robot vision. We are addressing these problems and testing some new concepts on the AMRF.

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Similarly we use the AMRF to evaluate new ideas for control of the factory including the computer interfaces. The AMRF consists of five work stations, each having a machine tool and a robot server. The stations are: horizontal milling center, vertical milling center, turning center, a cleaning and deburring station, and an inspection station. There is a hierarchy of controls, a central data base and mailbox, and a communications network. We have deliberately purchased or received on loan machines from as many different manufacturers as possible so that the number of interfaces among unlike devices is maximized.

We have developed a concept of neutral data formats such that all the disparate devices can communicate with each other. These formats serve as interpreters between pairs of devices that talk to each other via the central mailbox and database. The approach allows construction of a modular factory in which each device retains its proprietary nature and advantages. One can remove any device and substitute another with impunity providing only that the new device is fitted with the pre- and postprocessors necessary for operating with the neutral data formats.

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The AMRF will be fully operational by the end of fiscal year 1986 - all five work stations will be running and fully automated. We will then enter a period of research using the entire system to answer a number of questions we have. We are this month holding a work shop to see if industry has a set of research problems that might also be addressed using the AMRF. We plan to make the facility available to industry for such work.

The AMRF has attracted both support and collaborators from industry, academe, and other government agencies. We presently have 14 Industrial Research Associates, (senior technical staff from industry paid by their companies and working on the AMRF program). Loans or donations of equipment from industry total $ 3,300,000 to date. We have grants to 14 universities and collaborations with 22. We have a grant with the SUNY College of Technolgy on the subject of robot vision. The US Navy is a major sponsor in the work providing funds which nearly match the direct NBS funds. So the AMRF is a good example of close collaboration of the type all of us believe is a healthy and effective use of scarce resources.

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We have been engaged in this program long enough to draw some conclusions that are pertinent for this hearing. After several years of observing our team of engineers and computer scientists solve seemingly intractable problems it is my belief that technology will not be limiting, that given the staff, funds, and equipment we can devise a techical response to just about any problem in automation that may arise on the factory floor. This is not to say there aren't difficult challenges but rather that there will be a very large store of new technology accumulating over the next decade from research and development programs all over the world. The challenge is to take advantage of all this new knowledge in our production facilities, for only by putting the technology to use will there be an effect on our industrial competitiveness.

There are two barriers to the rapid adoption of this new technology. One is the slow pace of investment in the technology by top management; the other is the relative scarcity of trained personnel to install and operate fully automated factories. Studies by various groups indicate that management remains reluctant to adopt the new concepts of fully automated production probably for reasons grounded in tradition, inertia, and fear of the unknown. There are

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not yet enough examples of success to provide the kind of economic performance data that make investment in this technology a sure thing; adopting the new technology entails a fair amount of risk. We need much more microeconomic data on the advantages of automation.

The second barrier is lack of highly skilled personnel. I am not expert on the effects of automation on the labor force and there is much controversy about this. I do know that the factory of the future will require technically sophisticated staffing. No matter what you hear, the factory of the future will not be "unmanned." It may run by itself for periods of time (the graveyard shift for example) but not for long. Most of the time it will be supported by staff who must be intimately familiar with the operation of computer-controlled machinery, able to program changes in designs, capable of dealing with computerized data bases, interfaces and the like from the operating point of view. They will have to work with automatic feedback loops, robot technology, and advanced systems concepts. Such staff will also require the intuitive feel for the process that in the past has come from long association with machines and their eccentricities. This characteristic is what we now have in master machinists and tool and die makers. Such people are increasingly in short supply and in general do not have the computer skills that will be needed in the future. One assignment for our educational system is to help upgrade the craftsmen we now have through intensive continuing education programs. This

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is not retraining because we want to preserve their existing knowhow and graft on to it the new skills.

We'll need a great many new engineers for the factory floor with the skills listed above. I think the Nation's engineering technology programs can provide a great many of these people. The level of technical familiarity that an engineering technologist has would appear to be very well suited to the needs on the floor. As Gordon Millar, retired vice president of Deere & Co., has put it recently, engineering technology is "a new profession all its own that is based on the application of engineering principles to the physical operation of highly complex, computer-integrated manufacturing activities." I believe the SUNY College of Technology here at Utica can be a source of these highly prized factory engineers and I encourage the college to enhance the program in this direction.

In summary the technology of factory automation is coming and coming fast driven by the continuing explosive revolution in computer technology. For the Nation to reap the benefits in improved competitiveness that this technology surely offers, top management must make the necessary financial commitments and our educational system must supply the technically skilled personnel. Colleges and universities clearly have a key role to play both in doing research in factory automation and in educating a large number of technologists. Thank you Mr. Chairman. Mr. Kramer and I will be pleased to answer any questions the subcommittee may have.

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JOHN W. LYONS

Date of Birth: November 5, 1930

Birthplace: Reading, Massachusetts

Education: Degrees
Harvard University, A.B., Chemistry - 1952
Washington University, A.M., Physical Chemistry -1963
Washington University, Ph.D., Physical Chemistry -1964

Positions:
Director
National Engineering Laboratory
National Bureau of Standards

As Director of the National Engineering Laboratory, Dr.Lyons is responsible for NBS's research in applied mathematics, building technology, electronics and electrical engineering, energy conservation, engineering standards development, fire, manufacturing engineering, and chemical engineering.

From April to December 1983 Dr. Lyons served as the Acting Deputy Director of the National Bureau of Standards.

Dr. Lyons was Director of the NBS Center for Fire Research until December 18, 1977, and was responsible for providing scientific and technical knowledge applicable to the prevention and control of fires.

Dr. Lyons served in various research and development positions at the Monsanto Company from 1955 to 1973. He specialized in the chemistry and uses of phosphorus-based chemicals including fire retardants. He served from 1971 to 1973 as a member of the ad hoc panel of fire research, a National Academy of Sciences evaluation panel for the National Bureau of Standards.

Dr. Lyons is author of three books: Viscosity and Flow Measurements, The Chemistry and Uses of Fire Retardant, and Fire. He was co-author and editor of Fire Research on Cellular Plastics. He has contributed chapters to five other books and has written numerous papers and articles on technical or research topics. His early research interest was the physical chemistry of polyelectrolyte solutions, especially formation of complexes with metal ions. This work emphasized the behavior of inorganic polyphosphates and deoxy ribonucleic acid (DNA).

Dr. Lyons is a member of the National Academy of Engineering, a Fellow of the American Association for the Advancement of Science, a Fellow of the Washington Academy of Science, a member of the Naval Research Laboratory Naval Research Advisory Committee, a member of the Office of Science and Technology Policy Committee on Federal Laboratories, member of the American Chemical Society (past chairman of the St. Louis Section), member of the American Institute of Chemical Engineers and member of Sigma Xi. He serves on the Advisory Committee for Engineering, National Science Foundation; Advisory Council, College of Engineering, University of Maryland; Board of Directors, National Fire Protection Association. He served on a special committee of the Maryland State Board for Higher Education to study the needs for engineering education (1983-84). He was chairman of the Products Research Committee (1974-1979), a nine-member charitable trust administering a $5M research fund on fire research; co-chairman of the US-Japan Natural Resources Panel of Fire Research (1975-1978). He received the Presidential Management Improvement Award in 1977 and the US Department of Commerce Gold Medal, also in 1977. In 1981 he received the Presidential Rank Award of Distinguished Executive.

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STATEMENT OF DR. FRED DIAMOND, CHIEF SCIENTIST, ROME AIR DEVELOPMENT CENTER, U.S. AIR FORCE, ROME, NY, ACCOMPANIED BY DR. NORTHRUP FOWLER

Dr. DIAMOND. Mr. Chairman, Congressman Boehlert. Of course, it is an honor and a privilege to be given the opportunity to provide your subcommittee some comments relative to robotics.

My name is Fred Diamond; I am Chief Scientist of the Rome Air Development Center [RADC], one of several laboratories of the Air Force System Command.

Now, the mission of RADC does not involve robotics and its application to manufacturing techniques. I intend to emphasize other aspects of artifical intelligence, so-called knowledge-based systems. Now, this subject may be relevant from the aspect of applicable technology and the challenges of advancing the state of the art.

Dr. Patrick Winston, who is director of MIT's artificial intelligence laboratory, recognized leader in the field, defines artificial intelligence as "the study of ideas which enable computers to do the things that make people seem intelligent."

This includes the ability to reason and to acquire and apply knowledge. He predicts applications to farming, mining, manufacturing, education, medicine, offices, and households in tomorrow's world. To this end, computer scientists and engineers have addressed problems, such as intelligent data retrieval, automatic programming, perception, robotics, and expert consulting systems.

The latter, which involves knowledge of the area of application, are called knowledge-based systems, or expert systems, when the knowledge is derived from human experts.

Now, in the Air Force, the growing complexity of military weapons systems and the tremendous increase in the quantity and quality of information that must be assimilated and acted upon have the potential of overwhelming one's ability to react with accuracy and timeliness in critical situations.

Hopefully, this situation can be mitigated by greater use of automation for tasks involving knowledge, perception and reasoning. Thus, mindful of recent progress in so-called expert systems, the U.S. Air Force has been making significant R&D investments in this area. With the potential ability to accomplish complex problem solving requiring interpretation, prediction, monitoring, planning, and diagnosis, meaningful improvements can be expected in the cockpit, in command and control centers, in logistics, and even in the conduct of research and development.

Such R&D activities involving applications that depend on decisionmaking, problem solving, and automation encompass the mission, not only of the Rome Air Development Center, but also the Wright Aeronautical Laboratories and the Air Force Human Resources Laboratory.

The command and control process in particular depends heavily on human decision-making along with decision-support systems, such as provided by computer automation. Commanders, on the basis of information presented from sensor inputs, reports, directives, must perform such functions as situation assessment, mission planning, and resource allocation. Expert systems can assist com-

manders in accomplishing these tasks by providing needed data, alternatives and consequences.

Nowhere is the decision-making process more critical than in the cockpit of a high-performance combat aircraft. Here, the pilot must interface with his controls and weapons systems and evolve tactics based on his assessment of his situation and his resources. Now, potentially, expert systems can enhance the pilot's role as a weapons systems manager, and improve targeting, weapon delivery and survivability.

It is likely, however, that some of the most immediate and useful Air Force applications of expert systems may be in the area of diagnostics and maintenance. Faced with problems of personnel attrition, operational readiness can be greatly enhanced by minimizing the mean time to repair, and by accomplishing greater efficiency in training.

The Human Resource Laboratory is beginning a program to apply AI techniques in the area of maintenance aids in training. Objectives of the program include lower mean time for repair, greater operational readiness, a stabilized corporate experience base, enhanced personnel productivity, greater training efficiency, and decreased past loading on weapons systems personnel.

The approach is to develop an integrated system with the initial demonstration to be conducted as part of AFHRLs Integrated Maintenance Information System [IMIS] program.

The IMIS proposal is to provide all necessary automation for flight line personnel in one compact, user-friendly device. It would provide common data bases, user interfaces, reporting requirements, displays, hardware, and so forth, to aid, train, and support maintenance personnel. It would display the procedural data, aid in troubleshooting, present training material tailored to the specific person and task requirements, aid in personnel decisions, and eventually be able to change its internal knowledge representations based actually on its analysis of data bases.

Now, AI technology, such as robotics and computer vision, have proven useful in manufacturing in the commercial world, as we have heard. These and other artificial intelligence technologies for planning, scheduling, controlling manufacturing operations and shop floor applications in the aerospace factories of the space future will greatly benefit the technology base for manufacturing.

So, as part of its ongoing program to establish a science base in the manufacturing area, the Materials Lab of the Wright Aeronautical Laboratories is planning a program, beginning in fiscal year 1986, to develop AI applications for aerospace manufacturing.

The objective is to use artificial intelligence techniques to provide capabilities for more rapid response in changes in environment and software, provide a method to replace lost experts, and also knowledge based solutions to problems in planning, scheduling, control, and shop floor procedures.

Its approach is to establish an Institute for Artificial Intelligence in Manufacturing at a major university, competitor selected. Industry will be invited to participate on a cost-sharing basis, and, in return, receive immediate access to technology advancements, input to the research program, and access to the graduates.

This approach is expected to create a national resource for research into the use of AI concepts for batch manufacturing, stimulate rapid aerospace industry and university involvement in a growing technology for manufacturing, and provide a new source of people trained in AI manufacturing.

Now, the pursuit of programs, such as those I have outlined, include a vigorous meaningful program in basic research and exploratory development. The development of the technology base for artificial intelligence is the responsibility of the Rome Air Development Center, and I will discuss this in a little more detail.

Despite well-justified enthusiasm, we recognize that artificial intelligence offers no quick and easy solution to the problems addressed. In general, expert systems represent more art than science and more research is sorely needed.

Furthermore, despite the growth in the numbers of many self-acclaimed artificial intelligence specialists, it appears that the amount of talent available for research and development and for education and training is quite limited.

However, we, at the Rome Air Development Center, realize we cannot make a meaningful impact in this field simply by throwing money at the problem with the expectation of receiving major advances rapidly. Instead, we have taken the following approach: building up an in-house capability; promoting a meaningful research program; supporting the development of more expertise in universities; encouraging industrial support of research in universities; and encouraging industrial buildup of an in-house capability.

In essence, by pooling our limited talent, we can promote mutual growth. In order to foster development of competent researchers that could support RADC's Center of Expertise, the concept of a consortium of universities has evolved.

In support of the consortium, we have made a long-term commitment with significant funding to assure quality and continuity. Eight universities have entered into a 5-year, $8 million contract with RADC to conduct research in artificial intelligence. The institutions which are members of the consortium are: SUNY Buffalo, Clarkson University, Colgate University, University of Massachusetts, Rensselaer Polytech Institute, University of Rochester, Rochester Institute of Technology, and Syracuse University.

In addition, the Air Force Institute of Technology at Wright-Patterson Air Force Base in Ohio participated on a nonfunded basis. Each of these institutions brings some expertise to the consortium. Collectively, as an entity, they represent a far more powerful group. To exploit these expertises, foster growth in our resources, capabilities, and technology base, the consortium operates as follows:

First of all, RADC offers to promote strong interaction between the Air Force, the consortium and industry; share facilities with universities and interchange personnel; sponsor summer faculty and student resident programs and fellowships; support cooperative education programs emphasizing artificial intelligence; and encourage faculty sabbaticals at RADC.

On the other hand, we expect the consortium to practice strong interaction with other universities, industry and RADC; to establish ties with industrial leaders in artificial intelligence; solicit in-

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dustry sponsorship of artificial intelligence research in universities; and share facilities and expertise within each university.

The consortium has only been in being since January, but I am already impressed with their progress, not only in research but in their efforts at mutual cooperation and interfacing with universities.

In summary, we recognize the challenges in applying and extending the state of the art to useful, nontrivial solutions of Air Force problems. Current expertise is limited, and despite the promise of this technology, no overnight solutions are expected.

But with well-defined goals, growing progress, and continued commitment to the development of expertise, we are confident of our growing technology base and the evolvement of expert systems as effective tools in our military inventory.

Thank you.

[The prepared statement of Dr. Diamond follows:]

STATEMENT OF

DR FRED I. DIAMOND

CHIEF SCIENTIST

ROME AIR DEVELOPMENT CENTER
GRIFFISS AFB NY

Mr Chairman and distinguished members of the Subcommittee, it is an honor and a privilege to be given the opportunity to provide you with some comments relevant to robotics.

My name is Fred I. Diamond, and I am Chief Scientist of the Rome Air Development Center (RADC), one of several laboratories of Air Force Systems Command. The mission of RADC does not involve Robotics and its application to Manufacturing Techniques. I intend to emphasize another aspect of Artificial Intelligence (AI), so-called Knowledge-Based Systems. This subject may be relevant from the aspect of applicable technology and the challenges in advancing the state-of-the-art.

Dr Patrick Winston of M.I.T., a recognized leader in the field, defines Artificial Intelligence as "the study of ideas which enable computers to do the things that make people seem intelligent." This includes the ability to reason and to acquire and apply knowledge. He predicts applications to farming, mining, manufacturing, education, medicine, offices, and households in tomorrow's world. To this end, computer scientists and engineers have addressed problems such as intelligent data retrieval, automatic programming, perception, robotics, and expert consulting systems. The latter, which involves knowledge of the area of application, is called Knowledge-Based Systems, or Expert Systems, when the knowledge is derived from human experts.

In the Air Force, the growing complexity of military weapons systems and the tremendous increases in the quantity and quality of information that must be assimilated and acted upon, have the potential of overwhelming one's ability to react with accuracy and timeliness in critical situations. Hopefully, the situation can be mitigated by greater use of automation for tasks involving knowledge, perception, and reasoning. Thus, mindful of recent progress in

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so-called Expert Systems, the US Air Force has been making significant R&D investments in this area. With the potential ability to accomplish complex problem solving required interpretation, prediction, monitoring, planning, and diagnosis, meaningful improvements can be expected in the cockpit, in command and control centers, in logistics, and even in the conduct of research and development. Such R&D activities involving applications that depend on decision making, problem solving, and automation encompass the mission, not only of the Rome Air Development Center, but also the Wright Aeronautical Laboratories and the Air Force Human Resources Laboratory (AFHRL).

The command and control process in particular depends heavily on human decision making along with decision support systems such as provided by computer automation. Commanders, on the basis of information presented from sensor inputs, reports, and directives, must perform such functions as situation assessment, mission planning, and resource allocation. Expert systems can assist commanders in accomplishing these tasks by providing needed data, alternatives, and consequences.

Nowhere is the decision making process more critical than in the cockpit of a high performance combat aircraft. Here, the pilot must interface with his controls and weapons systems and evolve tactics based on his assessment of his situation and his resources. Potentially, expert systems can enhance the pilot's role as a weapons systems manager, and improve targeting, weapon delivery and survivability.

It is likely that some of the most immediate and useful Air Force applications of expert systems may be in the area of diagnostics and maintenance. Faced with problems of personnel attrition, operational readiness can be greatly enhanced by minimizing the mean time to repair, and by accomplishing greater efficiency in training.

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Perhaps the most ambitious program planned is the application of knowledge-based systems to software production. The objective of long-term R&D effort now underway is to provide a software assistant supporting all aspects of software development, resulting in improved programmer productivity and software quality.

The pursuit of programs such as those I have outlined includes a vigorous, meaningful program in basic research and exploratory development. The development of the technology base for artificial intelligence is the responsibility of the Rome Air Development Center, and I will discuss this in more detail.

Despite well-justified enthusiasm, we recognize that Artifical Intelligence offers no quick and easy solutions to the problems addressed. In general, expert systems represent more art than science, and more research is sorely needed. Furthermore, despite the growth in the numbers of many self-acclaimed Artificial Intelligence specialists, it appears that the amount of talent available for research and development and for education and training is quite limited.

However, we at the Rome Air Development Center realize that we cannot make a meaningful impact in this field simply by throwing money at the problem with the expectation of achieving major advances rapidly. Instead, we have taken the following approach:

a. Build up an in-house capability

b. Promote a meaningful research program

c. Support the development of more expertise in universities

d. Encourage industrial support of research in universities

e. Encourage industrial build-up of an in-house capability

In essence, by pooling our limited talent we can promote mutual growth.

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In order to foster development of competent researchers that could support RADC's Center of Expertise, the concept of a consortium of universities has evolved. In support of the consortium, we have made a long-term commitment with significant funding to assure quality and continuity. Eight universities have entered into a five-year, $8,236,000 contract with RADC to conduct research in artificial intelligence. The institutions which are members of the consortium are:

SUNY Buffalo	Rensselaer Polytechnic Institute
Clarkson University	University of Rochester
Colgate University	Rochester Institute of Technology
University of Massachusetts	Syracuse University

In addition, the Air Force Institute of Technology at Wright-Patterson Air Force Base in Ohio participated on a non-funded basis. Each of these institutions brings some expertise to the Consortium. Collectively, as an entity, they represent a far more powerful group. To exploit this expertise, foster growth in our resources, capabilities, and technology base, the consortium operates as follows:

RADC will:

a. Promote strong interaction between the Air Force, the Consortium, and industry.

b. Share facilities with universities; interchange personnel.

c. Sponsor summer faculty/student resident programs and fellowships.

d. Support cooperative education programs emphasizing Artificial Intelligence.

e. Encourage faculty sabbaticals at RADC.

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The Consortium is expected to:

a. Practice strong interaction with other universities, industry, and RADC.

b. Establish ties with industrial leaders in Artificial Intelligence.

c. Solicit industry sponsorship of Artificial Intelligence research in universities.

d. Share facilities and expertise within each university.

Although the Consortium has come into being only since January, I am impressed with their progress, not only in research but in their efforts at mutual cooperation and interfacing with industry.

In summary, we recognize the challenges in applying and extending the state-of-the-art to useful, non-trivial solutions of Air Force problems. Current expertise is limited, and despite the promise of this technology, no overnight solutions are expected. But with well-defined goals, growing progress, and continued commitment to the development of expertise, we are confident of our growing technology base and the evolvement of expert systems is effective tools in our military inventory.

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BIOGRAPHY

ON

DR FRED I. DIAMOND

Dr Fred I. Diamond is the chief scientist at the Rome Air Development Center, Griffiss Air Force Base, NY.

Dr Diamond received a bachelor of science degree in electrical engineering from the Massachusetts Institute of Technology. He also holds a master's degree and a doctoral degree in electrical engineering from Syracuse University.

Dr Diamond is responsible for the planning and conduct of research and exploratory development in C3I at RADC. Technical activities include communications, command and control, surveillance of ground and aerospace objects, intelligence data handling, information system technology, electromagnetics, solid state sciences, and electronic reliability, maintainability and compatibility.

Dr Diamond has been employed by the Air Force since 1950, first at Watson Laboratories, Red Bank, NJ, and at the Rome Air Development Center where he has specialized in signal processing for radar and communications. Prior to his present assignment, he was technical director of the Communications and Control Division, now the Communications Division, at the Center. Dr Diamond has also taught at Utica College of Syracuse University and at Syracuse University.

Dr Diamond has served on a number of Air Force and Department of Defense advisory and study groups. He currently is chairman of the Avionics Panel of the NATO Advisory Group on Aeronautical Research and Development. He is also executive chairman of the Communications Sub-Group of the Australian, Canadian, New Zealand, United Kingdom, and United States Technical Cooperation Program. He also chairs the Joint Directors of Laboratories (Army-Navy-Air Force) Technical Panel on Command, Control, and Communications.

He has been elected for Fellow of the Institute of Electrical and Electronics Engineers, a Fellow of the American Association for the Advancement of Sciences, and an Associate Fellow of the American Institute of Aeronautics and Astronautics. He is also a member of Eta Kappa Nu and Sigma Xi, professional honorary societies, and the New York Academy of Sciences. Dr Diamond is listed in Who's Who in America and Who's Who in Engineering. Among his Air Force awards are three Air Force Senior Executive Service Bonuses for Outstanding Performance, two Air Force Decorations for Exceptional Civilian Service, the Air Force Meritorious Civilian Service Medal, two Air Force Special Act Awards, a Sustained Superior Performance Award, and fourteen Letters of Commendation.

He is a member of the Massachusetts Institute of Technology Educational Council; a member of the advisory committees of the University of Massachusetts, Rensselaer Polytechnic Institute, and Syracuse University. He is also a member of the Board of Trustees of the Jervis Public Library of Rome.

He is married to the former Edna R. Hutt of Miami, FL. They have three children: Celia, Joel, and Shari.

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Mr. WALGREN. Thank you very much, Dr. Diamond.

Let me ask Dr. Lyons, you indicate $3 million contributed to the automated manufacturing center from the outside. What has been the level of support within the NSB for several years running?

Dr. LYONS. The inside operating budget is of the order of $6 million, and then there is reimbursable funding from the Navy and other sponsors of at least another $6 million. So, the total operating budget is on the order of $12 million.

Mr. WALGREN. That would be about 10 percent of the NBS overall budget.

Dr. LYONS. No, that is not correct, because you have to look at the Bureau budget as base plus reimbursable to make that, in which case it is about $200 million.

Mr. WALGREN. I see.

Dr. LYONS. So, it would be 12 divided by 20.

Mr. WALGREN. I would only note the congruency between your testimony and that of Dr. Nam Suh. You indicate that the barrier you see is management not investing in this area, and Dr. Nam Suh indicates that there is substantial timidity on the part of much of our industrial base. I gather they are moving their operations offshore to take advantage of the present known technology rather than investing in new technology.

Dr. LYONS. I gathered that from Nam Suh, and I agree.

Mr. WALGREN. Congressman Boehlert.

Mr. BOEHLERT. Dr. Diamond, you talk about building up in-house capability at RADC, and I know it has a world-wide representation, and the relationship you have with universities. You have a two-way exchange. In other words, are you giving out to the private sector some of the technical breakthroughs that you have? Is there a method for sharing some of the outstanding technical breakthroughs that are evident at RADC?

Dr. DIAMOND. Well, certainly. If I could sort of back up a little bit, first of all, that clearly competition with industry is the very cornerstone of the way we operate, and one of the things we do is that, which has been a very successful thing, is every year, we conduct a program called Industry Looks at RADC, in which we invite all industry, no exceptions, to come to RADC, and we spend several days making them aware of our progress and our ongoing programs.

Second is that the first—from the very professional point of view is that we encourage and promote our scientists and engineers to participate in symposiums and work shops where they can make people aware of what our progress is and what our accomplishments are, and, finally, of course, it is very important to publish results of one's work as well as publish the works of our contractors.

These publications are generally available within the bounds of releaseability and classification, of course, and, so, I think we do a pretty good job of coupling both universities and industries in terms of what our needs are, and what our contributions and results are.

Mr. BOEHLERT. The subcommittee is facing a problem. We just had a call from Washington, indicating that this afternoon, we are

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going to have some critical votes which will require both the chairman and me to return to Washington earlier than anticipated.

So, while I have a great number of additional questions for the panel, and I am sure the chairman does also, we know in the instance of Dr. Lyons and Mr. Kramer, we have access to you quite frequently, and, Dr. Diamond, you have always been most cooperative.

So, we will be back to you with some additional questions. Thank you very much.

The next panel will consist of Mr. George Peace of the Robotics International, Dearborn, MI, accompanied by Dr. Lewis Galbiati of our division of education training right here at the SUNY college of technology.

Mr. Peace, would you like to proceed? I apologize at the outset for the time constraints we are operating under, but the United States of America will be broke by the end of the day unless Congress does something, and we have to do something this afternoon.

STATEMENT OF GEORGE M. PEACE, ROBOTICS INTERNATIONAL, DEARBORN, MI, ACCOMPANIED BY DR. LOUIS GALBIATI, DIVISION OF EDUCATION TRAINING, ROBOTICS INTERNATIONAL, UTICA, NY

Mr. PEACE. We understand, Mr. Chairman and Congressman Boehlert, who I understand is one of the only Members of Congress that is a member of Robotics International, and it is nice to talk to a colleague.

Mr. BOEHLERT. Thank you.

Mr. PEACE. It is a pleasure and honor to present my comments at this hearing. I would like to begin by explaining briefly what Robotics International is all about.

Robotics International was formed in 1980, and is a technical association of the Society of Manufacturing Engineers. Its mission is to foster the exchange of information in the field of robotics for its membership and for the society at large for the advancement of technology to improve productivity and the quality of life.

RI/SME serves over 11,000 members worldwide and is the largest individual member association dedicated to robotics. For the past 9 years, Robotics International has conducted the world's largest annual expedition and conference on robotics.

The 10th annual robotics expedition and conference will be held in Chicago next April 1986, and I invite the members of the subcommittee to consider attending that conference.

In 1983, Robotics International commissioned and initiated a series of special DOD forums, which focused upon the U.S. Government's role in robotics research, development and application. We were honored to have Congressman Don Fuqua present a congressional viewpoint at that first DOD forum. We also had representatives from other government agencies, including the Army, Navy, and Air Force, DARPA of DOD, National Bureau of Standards, NSF, and NASA, participate at that meeting and succeeding meetings.

Since that first meeting, the forum has grown into the establishment of a military systems committee of Robotics International,

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whose primary objective is to develop stronger linkages between Robotics International and the Federal Government.

Recently, Robotics International conducted a comprehensive forecast of future trends of robotics in 1995. This survey was conducted by the University of Michigan on behalf of Robotics International, and included contacts with about 200 people involved in robotics, including managers, engineers, scientists, to determine where robotics is going over the next 10 years.

Because of the time limitation, I had some viewgraphs, but I will not show them. The copy of these are included at the end of the testimony. So, I will just refer to them.

Very quickly, the forecasts for sales of robotics in the United States, which is approximately 5,000 units annually, will reach 10,000 by the end of the decade and 20,000 units annually by the end of the century. Corresponding dollar sales are approximately $240 million in 1985 and will grow to about $630 million in 1995.

Several points that were made during the study include the recommended government action regarding the development of robotics, that I thought might be of interest to you. Particular recommendations include: direct funding and promotion of R&D, relaxation of antitrust laws to permit joint cooperative R&D, accelerated depreciation, government sponsored low-interest loans, and increases in secondary and college level education expenditures.

These are not recommendations of Robotics International, but are recommendations gleened out of a survey of approximately the 200 people that participated in the program.

I would like to make one other point. This is a personal point of view, but I will skip over most of my testimony, to emphasize that in the future, I believe that it is very important for the Department of Defense to play a more active role in development of robotics and automated manufacturing technology.

To a great extent, the Nation's largest resource for research and development comes out of the Department of Defense. The Department of Defense program in robotics and artificial intelligence is directed to two areas; one is coming out of the development of machinery, intelligent machine technology, which is focused, from my point of view, toward robotic maneuver forces, including air, ground-air, sea, and undersea-type vehicles; and also intelligent robots.

Both of these have a very common technology base that can be related not only to robotic maneuver forces, but also automated—flexible automated manufacturing.

I believe that a very central national issue is the development of robotics for both of these sectors, development of domestic manufacturing as well as defense manufacturing. In my view, the evolutionary development of robotics represents a synergistic march of progress in both economic development and national defense for a free world.

The strategic necessity for the free world, in particular the United States, is to take the initiative to make a major improvement in both our economic development and our military power where it is most needed.

Our military objective is to have an entirely adequate conventional nonnuclear deterrent. Our economic objective is to have the

United States enhance its leadership in the world economy. I view robotics as an opportunity to use intelligent machine technology to improve our manufacturing productivity to provide the basis for development of smart weapons for improved defense posturing.

The economic payoff would be significant, particularly since one can foresee a trend for a common technology base for domestic manufacturing in smart weapons. As I suggest, the subcommittee should have the Office of Technology Assessment assess the value, urgency, and need for having the Department of Defense strive for the development of smart machines for manufacturing as a test bed for the development of smart weapons.

An OTA study would hopefully lead to a DOD program that would keep the free world, and the United States in particular, in a leadership position with respect to economic development and at the same time, provide a strong military deterrent that stabilizes both ways.

Thank you very much.

[The prepared statement of Mr. Peace follows:]

ERIM

Statement of
George M. Peace
Member of the Board of Directors of Robotics International
of the Society of Manufacturing Engineers
and
Assistant to the President
Environmental Research Institute of Michigan

Before the
Subcommittee on Science, Research and Technology
of the
Committee on Science and Technology
U. S. House of Representatives

7 October 1985

Mr. Chairman and Members of the Subcommittee:

It is a pleasure and an honor to have the opportunity to present information regarding Robotics International (RI) of the Society of Manufacturing Engineers (SME) and some of my views concerning issues related to the role of automation and robotics in increasing and maintaining productivity and a strong manufacturing capacity in the United States.

I plan to briefly cover four topics that are relevant to this hearing. The topics include: 1) a description of Robotics International of the Society of Manufacturing Engineers (RI/SME) and its roles and mission, 2) selected highlights of a soon to be released RI/SME forecast of future trends in robotics through 1995, 3) my views on the impact of robotics technology on manufacturing organizations and 4) my personal recommendation that the Congress consider new policies that direct the Department of Defense to play a more active role in our nation's economic development via the development of intelligent machines for domestic manufacturing as well as for national defense. Regarding this last topic, I will suggest that the Subcommittee consider having the Office of Technology Assessment conduct a study to assess the potential of a broader DoD role in assisting the domestic manufacturing sector.

To provide some background for my remarks, let me begin by briefly reminding the subcommittee of the history of RI/SME, explaining my association with RI/SME and summarizing the history of the Environmental Research Institute of Michigan (ERIM) as it relates to our discussion today.

Robotics International, founded in 1980, is a technical Association of the Society of Manufacturing Engineers. RI/SME serves over 11,000 members worldwide, and is the largest individual member Association dedicated to the advancement of robotics. For the past nine years RI/SME has conducted the world's largest annual exposition and conference on Robotics. The 10th Annual Robotics Exposition and Conference will be held in Chicago in April 1986. In 1983, RI/SME initiated a series of special DoD Forums which focused on the U.S. Government's role in robotics research, development and applications. We were honored to have Congressman Don Fuqua present a Congressional viewpoint on robotics during the first Forum of this type. U.S. Government representatives from the Army, Navy, Air Force, DARPA, NBS, NSF, and NASA also participated in the 1983 and succeeding Forums. The Forum has since led to the establishment of an RI/SME Military Systems Committee whose objective is to develop stronger linkages between RI/SME and the Federal Government.

My personal involvement with RI/SME began in early 1980 with a special interest in improving the relationship between the domestic manufacturing sector and the Department of Defense, particularly in the applications of robotics for domestic and defense manufacturing, and the development of robotic maneuver forces. I remain an advocate for a stronger linkage between defense R&D and domestic manufacturing - an association which I am convinced can only further the best interests of both sectors.

The work being done at the Environmental Research Institute of Michigan demonstrates some of the benefits that can be derived from that linkage. ERIM, formerly known as the Willow Run Laboratories, was formed in 1946 in the University of Michigan to perform defense related contract research. In 1973 it separated from the University to become an independent, State of Michigan endorsed, non-profit contract research center. The principal focus of ERIM's activities has been, and continues to be, military reconnaissance and the civil remote sensing that grew out of that early defense research. In recent years the Institute has been active in transferring defense related technology to the manufacturing sector. During the past three decades, approximately 30 companies have spun off from ERIM to commercialize particular applications of machine vision and sensor technology.

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The Mission of RI/SME

The mission of RI/SME is to foster the exchange of information in the field of robotics for its membership and society at large for the advancement of the technology to improve productivity and the quality of life. RI/SME is organized into 11 technical divisions which are delineated below.

- Aerospace
- Education and Training
- Foundry
- Human Factors
- Material Handling Systems
- Mechanical and Electronics Assembly
- Military Systems committee
- Remote Applications
- Research and Development
- Robot Finishing Systems
- Welding

Members participate in those technical divisions relevant to their professional interest. The technical divisions represent the grassroots base for key areas in robotics technology which the RI/SME leadership draws upon to develop current and future programs. The pool of technical experts in each division provides guidance for planning workshops, seminars and national conferences and provides inputs to the RI/SME Board of Directors for development of long range plans and national strategies.

RI/SME publishes a wide range of technical information; a sample of which has been submitted to the Subcommittee. In the future, information relevant to the subject to this hearing will be made available to the Subcommittee. The RI/SME Board of Directors has requested that Catherine A. Bender, Manager of RI/SME, include the Subcommittee on the RI/SME mailing list. Ms. Bender also will serve as liaison to the Subcommittee on future requests for information and assistance.

Selected Highlights of the RI/SME 1985 Robotics Delphi Report

The University of Michigan, under the direction of Donald Smith and Peter Heytler, has recently completed a comprehensive forecast of future trends in robotics through 1995, and, in some cases through 2000. The project was sponsored by RI/SME and will be available for distribution during October 1985. A draft copy of the report has been provided to the Subcommittee. Upon publication, copies of the report will be provided to the full Committee if desired.

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The survey project was conducted using the Delphi method over a period of four and one-half years. The results reflect the collective opinions of several hundred forecast panelists who are managers, engineers and consultants employed by companies that use or produce robots, or that analyze industry developments. Major sections of the report include General Trends (markets), Technology, and Sociology.

Selected highlights of the report are outlined in the following slides.

Slide 1. Forecast of Sales of Robots in the U.S.

Domestic sales of robots, now some 5,000 units annually, will reach 10,000 units by the end of the decade and 20,000 units by the end of the century.

Slide 2. Forecast of Dollar Sales of Robots in the U.S.

Corresponding dollar sales projections are $240 million in 1985, $516 million in 1990, and $637 million in 1995.

Slide 3. Percentage Distribution of Robot Sales in the U.S. by Robot Applications

Actual numbers of robots purchased in the U.S. are expected to increase throughout the decade in all manufacturing areas.

Slide 4. Percentage Distribution of Robot Sales in the U.S., by Industry

The current leading consumer, the automotive industry, will account for a shrinking share of expanding total sales (51% now, 26% in 1995). The electronics industry is expected to play a leading role in the application of robots to assembly tasks, accounting for 14% of all unit sales in 1995. Assembly applications in all other industries will expand. The report predicts that in ten years approximately 25% of all new robotic installations will be in assembly.

Slide 5. Geographic Distribution of Robots in the U.S.

Regional activity in the design, development, and manufacture of robots is expected to mirror market activity. The East North Central States, home of the automotive industry, are expected to play a continuing leadership role in robotics (40% of user firms now, 28% in 1995). Pacific States with high electronic production are projected to gain a substantial share of robot use (12% of users now, 17% in 1995).

Slide 6. Percentage of U.S. Production Workers Displaced

Throughout industry, the overall displacement rate of workers by robots is forecast to reach 4.3% in 1995. In some industries, as many as 20% of the current work force may be displaced by robots, but within the group of affected workers, just 5-6% will actually be disemployed. Nearly 90% of displaced workers will remain with their current employers through lateral transfer, retraining or promotion. Among the remainder, half will take early retirement and half will seek other employment.

On the positive side, the U.S. manufacture of robots is expected to create a total of more than 45,000 jobs by 1995.

Slide 7. Recommended Government Action Regarding Development of Robotics

According to the panel, the following prospective government actions could be useful in the transition to advanced automation in production facilities:

- Direct funding and promotion of R&D
- Relaxation of antitrust laws to permit joint cooperative R&D
- Accelerated depreciation for robotic equipment
- Government-sponsored low-interest loans for purchase of automation equipment
- Increases in secondary and college-level educational expenditures.

The Impact of Robotics Technology on Manufacturing Organizations

The spread of microelectronic/robotic technology has reached such proportions that the technology is now projected to significantly alter social and economic conditions in the decades ahead. Developments in microelecronics, large-scale integrated circuits, computers, information collection and processing, mini-computers and/or microprocessors - all ingredients of future intelligent robots - have produced a technology revolution that will greatly expand the reach and impact of human brain power.

Without trying to describe the widespread major impacts that will result from this technological revolution, consider the following observations:

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1. This revolution will bring about major changes in nearly all aspects of the socio-economic system. No other "current event" opens so many varied and important business/economic opportunities, nor poses such problems for organizations that fail to "get with it".

2. It is very difficult to "get with it". Companies that have long been in communications, computers, avionics, and the like are already participating more or less effectively in the revolution, but many manufacturing and consumer-product oriented companies are only weakly coupled to the revolution.

The conclusion is that sectors such as manufacturing will undergo major changes in the foreseeable future; the extent to which companies assimilate and become leaders in the new technology will contribute substantially to their future well-being. In other words, the "new technology" is pervading all industry, rather than being confined to the electronics/communications sectors. Essentially all sectors will undergo transitions that will be rewarding for companies that are able to participate effectively, and traumatic for companies that fail to make appropriate adjustments.

These observations raise an important question: How does a sector such as the automobile industry, particularly the manufacturing-supplier sector, "get with it"? In general, the situation is as follows: the "new electronics/robotics" provides extensive opportunities for improved productivity, high reliability, increased automation, lower costs, and so forth. A wide array of organizations, from suppliers of small parts to large-scale assembly plants, will gradually assimilate these new opportunities---or become obsolete. The extent to which a company, a region, or a country efficiently accomplishes the assimilation in a timely fashion will determine to a significant degree its future well-being. However, the situation is very dynamic and it is not easy for any one organization to find its way intelligently and efficiently.

While each organization should take direct action, such as training and hiring skilled staff along with working on their own systems as both an operational and learning activity, it is basically not feasible for individual organizations to develop internal capabilities that fully deal with all current developments. The relevant creative work, the diversity of knowledge involved, and the crucial events are simply spread too far and too wide for any organization to internalize the action. Thus, in addition to

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appropriate internal activities, essentially all organizations must reach out and utilize as much of the existing and evolving expertise as possible.

The recent acquisitions of Electronic Data Systems, Inc. and the Hughes Aircraft Corporation by the General Motors Corporation, at high cost (on the order of $7-8 billion), exemplifies the need for automotive manufacturing concerns, even giants like General Motors, to assimilate the new technology. Many medium sized and some larger firms do not have the resources to acquire and internalize the new technology. Small business concerns are worse off.

In the near term, I can foresee an increase in acquisitions of high technology defense-oriented firms by manufacturing companies. This is only a partial solution. What is needed is a national strategy to use our high technology resources to assist the domestic manufacturing sector to the maximum extent possible.

Recognizing these issues, the Federal Government has recently created initiatives to address future problems associated with the assimilation of robotic technology in domestic manufacturing. These initiatives are in the form of R&D Limited Partnerships, establishment of R&D Centers of Excellence related to manufacturing technology (such as with NSF and NBS), and the NASA Automation and Robotics Technology Program for the Space Station and for the U.S. Economy.

These programs are focused in the right direction, but more can be done. A national strategy that provides improved linkages between our nation's vast manufacturing capabilities is needed. As reflected in Slide 8, new R&D partnerships should be explored to improve the linkage between domestic, defense, and space manufacturing sectors. My comments today are directed toward possible R&D partnerships between the domestic manufacturing sector and the defense manufacturing sector.

The DoD Role in Development of Robotics and Automation Technology

The rapidly increasing capabilities (and reliability) provided by microelectronics, along with decreasing costs, are producing major advances in all economic sectors (games, weapons, financial and management systems, etc.). In particular, dumb manufacturing machines are being replaced by smart machines. This development parallels the revolution occuring in weapon systems. The prospects for U.S. leadership in smart weapons and in smart

machines (and the associated industry base) would be greatly enhanced if we could develop greater synergism between DoD weapons research, manufacturing R&D, and the durable goods manufacturing sector. Intelligent robots, and the wide range of similar or associated technologies, have much in common for the factory and for the battlefield.

The role of intelligent weapons technology in the development of robotics/AI technology is illustrated in Slide 9. The two main spinoffs include robotic maneuver forces and flexible automated manufacturing. The technology base to support developments in these applications areas will emanate to a considerable degree from that associated with development of intelligent weapon systems. As a consequence, technologies associated with robotic maneuver forces and automated manufacturing are tightly coupled.

Flexible, automated robotic factories used by DoD organizations can serve as test beds (battlefields) for "intelligent robots". In this environment technologies such as synthetic vision, mechanical coordination, grippers, goal programming, locomotion, and related capabilities can be developed and put to use with pay-off in the near future in terms of the revitalization of our manufacturing sector and cost reductions in the manufacturing of materiel for DoD. Much of the technology needed for robotic maneuver forces can be perfected and low costs can be driven down in the manufacturing environment. Developments in this test bed environment would produce technological advancement with economic payoffs, and at the same time position the DoD and the defense industry for efficient development of cost-efficient robotic maneuver forces. Slide 10 illustrates how defense manufacturing/weapons R&D and domestic manufacturing could be coupled through the development of the intelligent machine test bed concept discussed above.

Thus, I suggest that the DoD robotics/AI program can be managed to serve the central long-term objective of fielding effective robotic maneuver forces, and at the same time can help modernize (and increase the productivity of) the manufacturing sector-with attendant reductions in the costs of future weapon systems. To the greatest extent possible we want, and almost should require, that new initiatives simultaneously serve more than one objective.

The natural long-term military objective for a DoD robotics/AI program is the development of robotic maneuver forces. A second objective is to apply such technology to defense production.

A third objective associated with the DoD robotics/AI program should be to aid the domestic manufacturing sector in the effort to apply intelligent machine technology to advanced factory automation. There may be some difficulties in trying to directly aid the domestic manufacturing sector. Roles and missions may be an issue as well as ways and means for the adequate coupling of differing organizations. However, current concerns with the costs of producing weapon systems and the related stagnation of much of our manufacturing sector provide an opportunity (e.g., in terms of congressional support) to service the domestic manufacturing sector on the way to the development of cost-effective robotic maneuver forces. The DoD procures hardware at a level of production which calls for robotics and/or flexible automation. New R&D partnerships that bring together intelligent weapons R&D, defense production, and domestic manufacturing could significantly increase national productivity.

The Subcommittee on Science, Research and Technology might consider the following type of question as part of its deliberations on the role of robotics and automation in increasing and maintaining productivity and a strong manufacturing capacity in the United States.

> Is it feasible to try to achieve greatly enhanced synergism between DoD R&D and the development of the technology base of the durable goods manufacturing sector (and related activities) - especially with respect to smart manufacturing machines and smart weapons (mid term) and/or industrial robot labor forces and military robot maneuver forces (long term)?

The study of this and related questions could lead to policies, practices, and programs for both the government and industry which would improve weapon systems and increase industrial productivity - both of which improve our defense posture. It might be appropriate to concentrate initial efforts on the more conceptual aspects of the question: projections of needs and technological opportunities, existing and desired barriers and bonds between government and industry in relation to the desired synergism, applicable data and organizational models, etc. In any event, initial efforts should provide people in government and industry with improved (and broader) concepts for more effectively assimilating the opportunities provided by the incorporation of intelligent machines/robotics in automated manufacturing and automated weapon systems.

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What I have tried to do in this part of my testimony is to describe what is, from my perspective, a central national issue. In my view, the evolutionary development of robotics represents a synergistic march of progress in both economic development and national defense for the free world. The strategic necessity for the free world, in particular the United States, is to take the initiative to make a major improvement in both our economic development and our military power where it is most needed. Our military objective is to have an entirely adequate conventional non-nuclear deterent. Our economic objective is to have the United States enhance its leadership in the world economy.

I view robotics as an opportunity to use intelligent machine technology to improve our manufacturing productivity and provide the basis for development of smart weapons for an improved defense posture. The economic payoff could be significant, particularly since one can foresee a trend toward a common technology base for domestic manufacturing and smart weapons.

Thus, I suggest that the Subcommittee have the Office of Technology Assessment assess the value, urgency, and means for having DoD drive the development of smart machines for manufacturing as a test bed for the development of smart weapons. An OTA study should hopefully lead to a DoD program that will keep the free world in a leadership position with respect to economic development and at the same time provide a strong military deterent that stabilizes the world politically.

A possible methodology for implementation of such a DoD program is shown in Slide 11. A target domestic industry and a DoD laboratory with common manufacturing problems should be identified. A working group should be established to analyze, in detail, various aspects of the manufacturing process used by both sectors, to identify the manufacturing problems and opportunities associated with the introduction of robotics/automation. The DoD laboratory should establish an advanced automated production test bed dedicated to a defense production problem. The automated factory test bed could be used to perform R&D on domestic and defense manufacturing problems as well as R&D on some aspects of intelligent weapons development. Several or many DoD laboratories of this type can be envisioned, each serving a different target industry and a different defense production problem of which there are many.

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Through appropriate linkages with other Government laboratories (DoD, DARPA, NSF, NBS, NASA, etc.) and the defense and targeted domestic manufacturing sectors, technology could be passed both ways in the effort to achieve a multiplicity of objectives.

By way of example, my last slide lists typical DoD laboratories and associated domestic target industries that could be linked together to form new DoD/Target Industry R&D partnerships. In the early stage of development, DARPA could play an active role in exploring and experimenting with new R&D partnerships between DoD and the domestic manufacturing sector since one of DARPA's missions is to develop new technology (the Strategic Computing Program) and conduct demonstration programs.

Thank you for giving me the opportunity to talk to you today. I know that if we pull together we can achieve our twin goals of economic leadership and a stable defense posture - and I am both excited and honored to be involved in that effort.

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Slide #1 IR-85-464

Forecast of Sales of Robots in the U.S.
(Thousand of Units)

Year	1984 Forecast		1981 Forecast	
	Unit Sales	Annual Growth Rate	Unit Sales	Annual Growth Rate
1981	---	--	2,300	--
1982	---	--	3,000	30.4%
1983	---	--	4,300	43.3
1984	4,200*	--	6,000	39.5
1985	5,000	19.0%	8,000	33.3
1986	6,000	20.0	---	--
1987	7,000	16.7	---	--
1988	8,200	17.1	---	--
1989	9,500	15.9	---	--
1990	11,000	15.8	---	--
1995	15,000	6.4	---	--
2000	20,000	5.9	---	--

*Actual year-end 1984 figure.

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Slide #2

Forecast of Dollar Sales of Robots in the U.S., by Application
(In Millions of 1983 Dollars)

	1985		1990		1995	
	Unit Sales	Total $ (mil.)	Unit Sales	Total $ (mil.)	Unit Sales	Total $ (mil.)
Machine tending	800	28.0	1,650	61.1	2,250	69.8
Material transfer	800	28.8	1,650	62.7	2,250	78.8
Spot welding	1,300	78.0	1,650	95.7	1,500	75.0
Arc welding	500	30.0	1,100	66.0	1,350	78.3
Spray painting	500	30.0	1,100	66.0	1,050	63.0
Processing	250	11.3	770	38.5	1,050	62.0
Electronics ass'y.	300	10.5	1,320	52.8	2,100	66.4
Other assembly	250	8.8	880	30.8	1,800	63.0
Inspection	250	13.0	770	38.5	1,500	75.0
Other	50	2.0	110	4.2	150	6.0
Totals	5,000	$240.4	11,000	$516.3	15,000	$637.3

Slide #3

Percentage Distribution of Robot Sales in the U.S., by Robot Application

	1985	1990	1995
Machine tending	16%	15%	15%
Material transfer (excl. machine tending)	16	15	15
Spot welding	26	15	10
Arc welding	10	10	9
Spray painting/coating	10	10	7
Processing*	5	7	7
Electronics assembly	6	12	14
Other assembly	5	8	12
Inspection	5	7	10
Other	1	1	1
	100%	100%	100%

*Includes such applications as routing, drilling, grinding, etc.

Slide #4

IR-85-458

Percentage Distribution of Robot Sales in the U.S., by Industry

	1985	1990	1995
Agriculture	1%	1%	1%
Mining and extractive	1	2	2
Construction	0	1	1
Electricity generation	1	1	1
Consumer non-durables	2	5	5
Non-metal primary commodities	2	4	5
Primary metals	3	4	5
Non-metal fabricated commodities	5	6	6
Fabricated metal products	10	8	8
Machinery	8	10	11
Electronics/precision equipment	8	10	16
Automotive	51	38	26
Aerospace	6	6	8
Other transport equipment	2	3	4
	100%	100%	100%

Slide #5

Geographical Distribution of Robots in the U.S.

	1985	1990	1995
New England	10%	11%	11%
Mid-Atlantic	10	11	10
South Atlantic	8	9	9
East North Central	40	34	28
West North Central	5	5	6
East South Central	5	5	6
West South Central	5	5	7
Mountain	5	5	6
Pacific	12	15	17
	100%	100%	100%

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Slide #6

Percentage of U.S. Production Workers Actually Displaced as a Result of the Installation of Robots, by Occupation

	1985	1990	1995
Assemblers	2%	5%	10%
Inspectors	1	3	6
Packers (excl. meat & produce)	1	2	5
Production painters	5	10	20
Welders and flamecutters	5	10	20
Machinists & machinery oper's.	3	10	13
Tool and die makers	0	1	2
Metalcraft workers	1	3	6
Construction crafts	0	0	1
Textile workers	1	2	5
Mining workers	0	2	4
Agricultural workers	0	1	2

Slide #7

Rank (from 1 to 5) the Degree of Usefulness of Positive Federal Government Action on Each of the Following Issues

	Degree of Usefulness[1]
Direct funding and promotion of research and development	2
Relaxation of antitrust laws to permit joint corporate research and development	2
Accelerated depreciation for robotic equipment	2
Direct tax breaks for robot purchasers	2
Government-sponsored low-interest loans to potential robotics or other automation purchasers	2
Increase in secondary and college-level educational expenditures	2

*1 = very useful; 5 = not at all useful.

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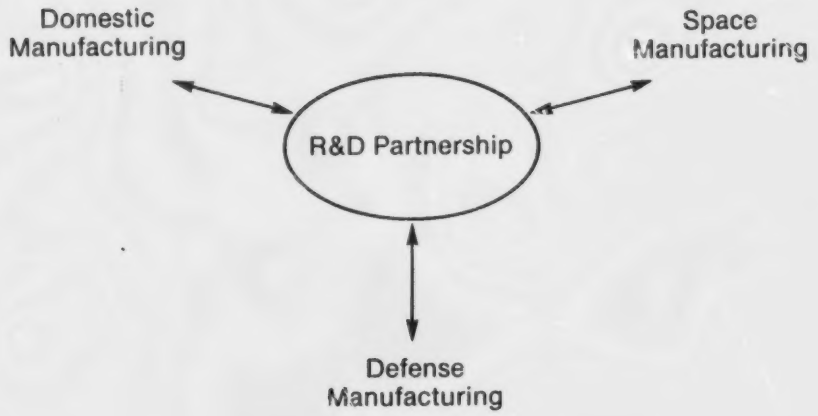
Slide #8

A National Strategy is Needed to Strengthen Our Overall Manufacturing Capability



Slide #9

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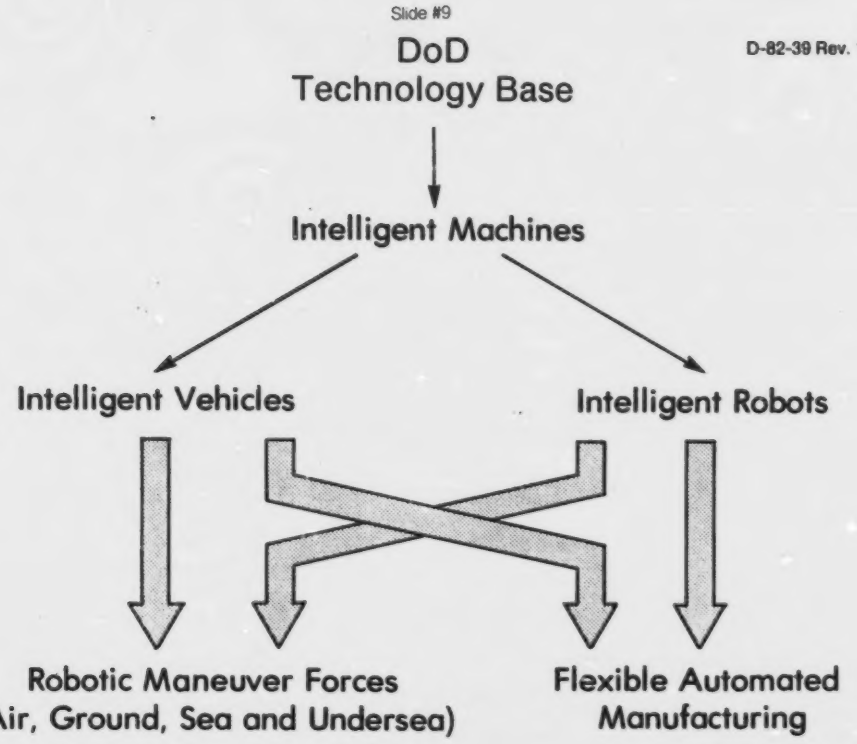

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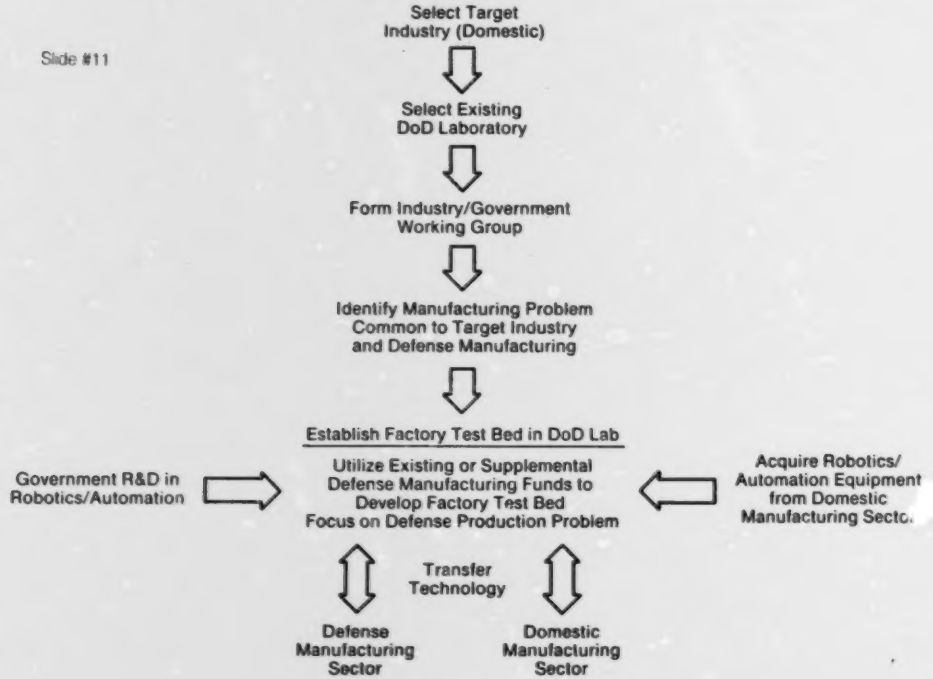
Slide #10

IR-83-507 Rev. 2

METHODOLOGY FOR DEFENSE/DOMESTIC MANUFACTURING R&D PARTNERSHIP

IR-85-457

Slide #11


Select Target Industry (Domestic)
Select Existing DoD Laboratory
Form Industry/Government Working Group
Identify Manufacturing Problem Common to Target Industry and Defense Manufacturing
Establish Factory Test Bed in DoD Lab
Government R&D in Robotics/Automation
Utilize Existing or Supplemental Defense Manufacturing Funds to Develop Factory Test Bed Focus on Defense Production Problem
Acquire Robotics/ Automation Equipment from Domestic Manufacturing Sectc
Transfer Technology
Defense Manufacturing Sector
Domestic Manufacturing Sector

Slide #12

ILLUSTRATIVE DoD/TARGET INDUSTRY R&D PARTNERSHIPS

DoD Labs	Domestic Target Industries
TACOM/Army	Automotive
HDL/Army	Electronics
MICOM/Army	Electronics
China Lake/Navy	Electronics
David Taylor R&D Center/Navy	Shipbuilding
NOSC/Navy	Electronics
AFWAL/AF	Aircraft
Rome Air Development Center/AF	Computers

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VITA

George M. Peace

George M. Peace received his B.S.E.E. and M.S.E.E. degrees from Auburn University in 1959 and 1960 respectively. His experience enecompasses design engineering, research and development, project management, marketing, planning and business management, all associated with defense related R&D. He has held positions with Auburn University, Bendix Research Laboratories, Chain Lakes Corporation and Willow Run Laboratories of the University of Michigan. His current position is assistant to the president at the Environmental Research Institute of Michigan.

In his current position his responsibilities include the development of new program areas for the Environmental Research Institute of Michigan (ERIM). In this regard he organized and managed a program at ERIM sponsored by the Economic Development Administration identified as The Potential Role of Community Colleges in the National Technology Transfer Program (aspects of this program were subsequently continued by the National Association of Community and Junior Colleges).

He formed the Intelligent Machine Technology Department at ERIM to develop intelligent machines that use various types of sensors integrated with machine vision, robot manipulators, and artificial intelligence techniques. As an off-shoot of this activity, he was also involved in forming Synthetic Vision Systems, Inc. (Ann Arbor), where he served as interim president before management of the company was turned over to individuals from private industry.

His current assigment is program manager for a program related to the devlopment of sensor systems for advance conventional defense applications.

His involvement in Robotics International of the Society of Manufacturing Engineers (RI/SME) began in 1980. He formed the Ann Arbor Chapter of RI/SME, organized and conducted DoD Forums of the 1983, 1984 and 1985 RI/SME International Conferences. As a current member of the RI/SME Board of Directors, much of his attention has been directed toward the Military Systems Committee.

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PROFILES

ROBERT N. STAUFFER, Managing Editor

The DOD and Robotics

The Department of Defense (DOD) is the major source of risk capital for new technology in this country. If an effective system of interactive communications can be set up and maintained, there is the potential for a highly significant payoff for both the defense and civilian manufacturing sectors.

This observation comes from George Peace, who is something of a crusader when it comes to the importance of technology transfer between these two groups. His efforts played a role in the formation of the new Military Systems Committee of Robotics International of SME (RI SME).

Peace is assistant to the president of the Environmental Research Institute of Michigan (ERIM) (Ann Arbor, MI). The work of this nonprofit research institute primarily involves federal contract research and development, although programs are also conducted for private industry.

"In the robotics area," says Peace, "we are essentially focused on sensor technology and image processing technology. We're integrating these technologies to create what we call an Intelligent Machine Technology base. This involves intelligent machines that use various types of sensors integrated with machine vision, robot manipulators, and artificial intelligence (AI) techniques. We view robotics from a total system perspective."

Peace organized the Intelligent Machine Technology Dept. at ERIM to formalize this effort. As an offshoot of this activity, he was also involved in forming Synthetic Vision Systems, Inc. (Ann Arbor), where he served as interim president before management of the company was turned over to individuals from private industry. In still another endeavor, Peace started the Ann Arbor chapter of RI SME (now the Michigan Robotics Research Council) in 1980. As a current member of the RI SME Board of Directors, much of his current attention is directed to getting the Military Systems Committee up to speed.

Committee Goals

"I firmly believe that the DOD will be the major developer of high technology related to robotics in the future," says Peace. "To some extent there has been a lack of communication regarding many aspects of military R&D programs. Much of this information is unclassified and readily available to private industry. The same situation exists in the flow of information the other way.

"There's much to be gained if we can facilitate the exchange of information," he continues. "Inflation and mounting pressure to cut back government spending make it imperative for DOD suppliers to use the most cost-effective manufacturing methods to improve quality and reduce costs. Also, in the future the DOD will rely increasingly on the economic strength of the US manufacturing sector to keep material in the field up to date. There must be a strong manufacturing technology base if the DOD is to acquire upgradable modules for continuing improvement of its equipment."

Peace notes that much of the nation's future robotics and AI technology base will come from the development of intelligent machines for DOD needs. With this background, he points out that the mission of the Military Systems Committee is to stimulate interactive communications between all sectors of the DOD and the country's defense and civilian manufacturing sectors.

The committee evolved out of DOD forums held at Robots 7 and 8 in 1983 and 1984, respectively. It held its first meeting at Robots West in November 1984 and is planning another forum during Robots 9. Peace is ad hoc chair of the committee.

Peace stresses that the committee is not concerned with the use of robots in connection with weapons. "Instead," he explains, "it is involved with robotics related to defense manufacturing and other applications such as soldier support, logistics, reconnaissance, and autonomous vehicles for hazardous tasks."

PEACE OF ERIM
Crusading for technology transfer.

The Payoff

"Technology transfer works both ways," says Peace. "The DOD spends billions annually on its R&D programs. More of this technology can come back to the private sector to help increase manufacturing productivity, particularly as it relates to small business. The committee is charged with identifying those technological opportunities that can help improve the productivity and efficiency of both the defense and civilian industrial sectors through the assimilation of robotics technology."

Peace urges RI SME chapters to play an active role in developing the new committee and suggests that interested individuals contact Dave Visscher at RI SME, One SME Dr., P.O. Box 930, Dearborn, MI 48121, (313) 271-1500, Ext. 354. ■

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Mr. BOEHLERT. Thank you.

Dr. Galbiati.

Dr. GALBIATI. Yes. Congressmen Walgren and Boehlert, I would like to thank you for this opportunity——

Mr. BOEHLERT. Could you get a little bit closer to the microphone?

Dr. GALBIATI. I am going to abbreviate my talk here because I understand you are short of time, but I think all the previous talks reinforce one thing, that is that there are very critical needs in terms of productivity and that we must do something at this point in time or the trend will not be changed.

What we are doing up to current times clearly has been correct. There is some concern about robotics on unemployment, but I think you must look at robotics in a bigger sense, and that is that robotics are the competitive manufacturing, that without robotics we cannot have competitive manufacturing.

The number of jobs per se given a one on one that every time a plant becomes less competitive and moves overseas, there is a whole bunch of auxiliary jobs that go with it.

There were three main needs, as far as I can see, in terms of the robotics field. One is in terms of faculty, the other is the trend to technology knowhow for small industry. This today is a very critical mark. It is not being done. People are afraid of it and so they are not acquiring the robotics to increase their productivity in the small shops of 100 to 150 people.

The third item is how to fund all this. I think I have probably the biggest data base in terms of what the state of robotics is in this country, and I have gone over a long period of time. The data is put forward, but I think as you look at it, I will sum it up very quickly, and that is that robotics education is growing in every part of the country.

Those parts started early in the central United States, near the auto industry, and you can see the other areas catching up. We also see one very important development, and that is the last survey included items in terms of vision research, robotics research, and what we are seeing is a 22 percent of those responded do have research that says that 5 years from now, robots are going to be smarter than they are now.

There are other implications in this because it fits into other aspects of automation. The third item was that if you look at the data, it says that all of the universities, about 80 percent now, have robots. The real dilemma is that they are buying because of cost and so forth, they are not buying the correct robots, that they have to go to the cheaper versions vs. the complex industrial type. So, this is clearly a major problem.

The fourth item was the faculty is a major problem, and you heard that over and over again, the development of faculty is very, very critical.

If we look at the data here at the college of technology, I was alarmed because I am falling into the same trap, and that is that in the past 7 years that we have been in business here, we have hired about 28 people. Of those, 16 were foreigners. We could not operate without them. Ten were direct imports. We went to England, Canada, to get them in. I should be ashamed of myself, but

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that is the way it goes. Four were secondary people who either came in through students at universities or we took them out of there, and we had to change their visa, but almost 10 or 12 of these required visa action. The Immigration Department has been very cooperative, and we will admit, nine were Americans.

We lost people, approximately 10 people; 4 went to industry because of higher, considerably higher salaries, and so forth. Four went to universities where there was more research, and they were allowed to continue their growth. Two went to other universities because their wife worked there and they had to move and so forth.

But, it almost seems that just teaching alone without the research component that you cannot maintain your technical competence, and even if you stay, you are going to be out of date. So, this, to me, is No. 1 critical item.

The next item has to do with getting the knowledge out to the small plants. The GM, the IBM, and GE are not concerned because they are hiring enough new people that they bring the new technology in. The small plants has been hit by competition in cutting back, one, are not hiring, or they do not have that many engineers, and they are not aware of what automation can do for them.

So that what I see, as I look across the country, is a need for something very equivalent to the old agricultural extension service. If we looked at that about 100 years ago when it was put in, there were 2 components. One was the experimental station, the other was the extension service.

I think the centers being funded by National Science Foundation are equivalent to these experiment centers, where you are doing the basic research, but we do not, anywhere that I can see, have a component that is helping to give that technology out where it can be used, and unless we get that component of the economy up to the productive stage, the whole thing is going to go down, and it is with very much concern, when I look at these figures, that we are funneling aid to research at about four times the robotics research, and I think the impact on people is much, much larger.

And, the last one on how to fund it, here I was—in my paper, you will see I suggested that it be almost as a component of the budget, both on agency and on defense contractors. If we took so much as one-eighth of a percent, then you would find that the amount of funding that would go in to build the infrastructure, manufacturing, would be enough as far as I can see it so that it would bring the State back into line.

But it has to be not—I think it is a good idea because the administrators are opposed to it, so it will probably work, but, in general, if you put it—as you talk to each agency, they will say yes, we are doing it, we have something in place, but the trend shows that it is not working.

If you put this thing as a percentage of their budget, it is not available to them any other way, then if the new budget process goes through in Washington where they are going to reduce everything, if we do not get it on to paper, it means that you just do not cut out the part that is going to the universities.

Without the mandatory part in there, you will not have the continuity, and you do not have the incentives to go out there and get it into the smaller universities, you have got to have it dispersed.

So, that is the summary of all my thoughts. Got it by the bell.
[The prepared statement of Dr. Galbiati follows:]

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ROBOTIC EDUCATION AND TRAINING GROWTH PATTERN

GEOGRAPHICAL AND SIX YEAR TRENDS

by

Louis J. Galbiati, Jr.

RI/SME Education and Training Division

SCIENCE, RESEARCH AND TECHNOLOGY SUBCOMMITTEE HEARING

October 7, 1985

Utica, New York

NEED

There is a critical national need to improve the level of education and training of our work force in automation and robotics if the United States is to maintain a vibrant manufacturing capacity. The latest technology must be applied to all levels of industry in order to increase national manufacturing productivity to a level where it is competitive. The need to improve industrial productivity is substantiated by the staggering balance of payments deficit and the increasing trend to transfer manufacturing operations to off-shore locations. While the use of manufacturing facilities in foreign countries reduces direct incremental manufacturing cost of products in the market place, the total cost to society may be beyond what can be tolerated. A number of steps must be implemented at this time before conditions deteriorate to a point of no return.

SURVEY OF ROBOTIC EDUCATION AND MACHINE VISION

In order to obtain quantitative data on the state of education in the Robotic field, I initiated a research program in the late 1970's while I was at the University of Arkansas. The effort was designed to determine educational activities at American colleges and universities in the robotic field as a function of geographical area and as a function of time for each geographical area. The work has been continued here at SUNY with the sponsorship of the Society of Manufacturing Engineers (SME). The results up to 1983 were presented in the "Regional Comparison of Robotic Education" paper at the 2nd Canadian CAD/CAM and Robotics Conference. The research is continuing with the latest survey completed in June 1985. The survey geographic areas are shown in Figure 1.

A preliminary analysis of the data on the 1985 SUNY/SME survey has been performed on the basis of colleges with two-year associate degree programs and of those with four-year baccalaureate and graduate degree programs.

The study of the new data in conjunction with the previous data indicates that the very rapid expansion rate reported in 1983 has tended to decrease and that the number of educational units is tending to stabilize.

The June 1985 SUNY College of Technology survey conducted under SME sponsorship included questions on the extent of robotic vision education activities as well as the questions on robotics. The data have been analyzed to determine the extent of instruction in machine vision and of machine vision research activities. Survey results are tabulated by year in Table 1 and by geographical area in Table 2.

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FIGURE 1. **GEOGRAPHIC LOCATION OF THE SURVEY AREA**

ROBOTIC SURVEY AREAS

Several years ago I decided to look at two aspects of the movement; one was the changes that were occurring with time and the other was the geographical distribution of Robotic educational activity. Surveys were used to obtain data on the changes with time. In addition, the country was divided into seven regions, as shown in Figure 1. Generally speaking, Area 1 is New York and Ontario, Area 2 is New England, Area 3 is the Northern Central region from Minnesota to New Jersey. Area 4 is the Eastern Southern region from Virginia to New Mexico; Area 5 is the Central U.S. from Arizona to Montana and North Dakota. The West Coast states and Hawaii are in Region 6

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TABLE 1:

Survey Results by Year

	1979	1982	1983	1985
Degrees	0	-	17	23
Canadian Programs	-	-	10	16
Robotic Instruction Courses	24	97	175	197
Institutions Having Robots	-	-	59%	83%
Institutions Planning to Buy Robots	-	-	56%	37%

TABLE 2: Survey Results by Geographical Region

Region		1	2	3	4	5	6	Total
# Replies	83	60	27	100	89	45	36	354
	85	54	14	66	51	37	7	243
Degree Prog.	85	3	2	12	3	2	1	23
Institutions Having Rob. Courses	82	10	5	48	22	6	6	97
	83	20	12	67	42	16	18	175
	85	47	10	53	40	32	15	197
Institutions Having Robots As Part of Other Courses	(#)83	37	16	65	50	20	21	209
	85	34	9	43	36	27	10	160
	(%)83	62	69	65	56	44	58	59
	85	36	64	99	70	73	48	66
Institutions Having Robots	(#)83	27	16	65	48	22	19	195
	85	47	9	56	42	30	17	201
	(%)83	45	59	64	54	49	53	56
	85	87	64	82	81	81	81	83
Institutions Planning to Buy Robots	(#)83	27	16	63	48	22	19	195
	85	27	7	25	16	10	6	91
	(%)83	45	59	64	54	49	53	56
	85	50	50	38	31	27	29	37
Vision Instruction	(#)85	19	6	32	18	14	5	94
	(%)	35	42	48	35	38	24	39
Vision Research	(#)85	10	3	15	10	11	5	54
	(%)	19	21	23	20	30	24	22

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At the bachelor and graduate level, 9% of the universities had separate machine vision courses, 30% included machine vision as part of some other course, and 22% had machine vision research in progress. At the associate degree level, 3% of the colleges had separate courses on machine vision and 21% included machine vision as part of some other course.

The results are significant in that they indicate the current state of machine vision instruction is similar to the state of robotics in the 1980 time period, as determined by the surveys conducted during that period (1, 2).

In the early 1980's, the robotic technology was included in the curriculum of very few colleges with associate degree programs; the amount of robotic activity at the baccalaureate and graduate levels was about double that at the associate degree level (1, 2).

It is projected that machine vision will experience an even greater growth of inclusion in the educational programs in the next five years than that experienced by robotics during the past five years, based on the rapidly decreasing cost of equipment, the critical need for productivity improvement, and the increased application of machine vision in manufacturing equipment, as demonstrated by the industrial exhibits in Robot-9. This trend will continue to accelerate as engineers become more familiar with the technology.

Vision sensors will complement Tactile sensors since the Tactile sensors are simpler and lower in cost. However, it is expected that, as the cost of vision systems decreases and the knowledge of digital imaging technology becomes commonplace in the years ahead, the vision sensors will find wider application. Currently, a simple vision system can be acquired for less than $20,000.

It is clear from the data in tables 1 and 2 that the universities were responsive to this national need and provided education robotic experience for the students in our engineering technology and engineering programs. However, there are major problems of maintaining facilities and laboratories as well as devising new delivery vehicles which will reach the small shops and factories in our country.

TECHNICAL APPLICATION WORKSHOPS

SME/RI which has been the most active professional organization in the field of workshops aimed at introducing new technology to industry conducts some 500 workshops per year with an average attendance of 30 individuals per workshop, for a total of 15,000 persons per year. The workshops are expensive and generally are attended by engineers from larger industries.

While the workshops are aiding in the task of transferring new technology to faculty and laboratories, there is a shortage of competent faculty members with robotic experience, and equipping adequate laboratories is a major problem. The survey indicated that many of the colleges and universities are acquiring non-industrial type robots.

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FACULTY AND APPLICATION RESEARCH ACTIVITIES

The faculty recruitment problem is due to the economics of our times. New graduates with a B.T. degree are starting work in industry at salaries very close to that paid to the faculty members. In addition, it is difficult for the faculty members to obtain research funding needed to maintain their technical skills, and the rigid conditions imposed by the TIAA/CREF at retirement does not provide appropriate alternatives.

This latter condition could be remedied at no cost if congress passed a law which would require TIAA/CREF to give the individual the option at retirement of transferring his retirement funds to his own IRA account. Currently, they are not given this option and the annuity offered by TIAA is not competitive as evidenced by the schedule in Appendix A. The enactment of the option would be in the spirit of deregulation, would force TIAA to be competitive and provide the faculty member with flexibility at retirement.

This is a national problem. A number of leading universities, including Johns Hopkins University, have withdrawn from the TIAA system because of the inflexibility. As a result, individual faculty members are forced to have many separate retirement plans if they are active during their educational career.

The funding of research on technology applications can be remedied via a small set aside requirement on governmental laboratory/agency budgets and on defense contracts. It worked for Equal Opportunity and it would be effective for technical education. This would have the advantage of continuity over the years and provide increased interaction between education, governmental units and industry.

INFUSING NEW TECHNOLOGY IN SMALL PLANTS

A mechanism for infusing new technology application knowledge into the small plants must be developed if the upgrading of our industrial base is to occur. One can consider this as a function similar to that performed for rural farming by the Agriculture Extension Service years ago. The University Centers sponsored by NSF serve a special class of larger industries and do little for small factories which we must upgrade to increase national manufacturing productivity.

The University Centers can be considered as the Agriculture Experiment Stations. What is required for the application of technology on a broad basis is an organization akin to the Agriculture Extension Service: we can call it the TECHNOLOGY APPLICATION EXTENSION SERVICE.

The extension service approach would provide a mechanism for delivering new knowledge and application ideas to the small shops and manufacturing plants. This concept should be implemented on a pilot project basis in a number of different states to determine the feasibility and practicality of the approach. The extension service concept could be broadened to include providing equipment to the service for short term demonstrations and application research projects. This equipment would serve a dual purpose in that it would be available to students for "hands-on" experience. I feel that the Engineering Technology programs would be the most appropiate locations for the service; they are application orientated as contrasted to the basic research of the Engineering programs.

The creation of the Technology Application Extension Service would also contribute to the faculty development activity in that it would provide a means of maintaining technical skills on industrial type equipment and a source of additional compensation. would be

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TECHNOLOGY RESEARCH CONTRACTS

The Robotics and Automation type educational programs are frequently located at a small or a relatively new educational institution. The net effect of this is that it is fairly difficult or perhaps almost impossible for these institutions to obtain research contracts from the government labs or agencies. The area of interest would be towards the application of technology as contrasted to basic research.

The effectiveness of such research contracts is demonstrated by the one we have received from the National Bureau of Standards The contract has had a major impact on the upgrading and development of the robotic instructional program at the college and is resulting in the infusion of this technology in local industry. The project has enabled the college to implement five courses in machine vision, enabled us to win two additional research grants, resulted in special application projects being implemented in three local medium sized industries, and has enabled our faculty to be exposed to many new concepts at the NBS facility.

We are exploring means of establishing a similar activity with the Rome Air Development Center in the area of machine vision and other high technology fields. Such an arrangement would benefit both organizations and also the manufacturing industries in the region. I feel that there is a sincere interest at RADC to establish the relationship since it would provide the continuity which is essential for maximum results and would provide the College with a source of application problems for students to work on in their application projects courses. I feel that a national requirement of a small percentage of budget on government laboratories would do much to stimulate such activities as the funding would no longer have to come out of the government researcher's project budget. The researcher would have everything to gain by utilizing his time to establish such projects.

ACTION ITEMS AND RECOMMENDATIONS

1. Implement by legislation or regulation a requirement that TIAA/CREF provide each individual with the option of transferring the value of his retirement account to his own IRA account at retirement.

2. Implement several Technology Application Extension Service pilot projects to determine the best method of applying technology to upgrade the productivity of small shops and factories employing fewer than 100 or 150 people.

3. Require a small percentage set aside at the budget level of all government laboratories and agencies for small technical research contracts to educational institutions for technology application research.

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APPENDIX: [illegible] RATE SCHEDULE TO BE EFFECTIVE ON JANUARY 1, 1986
FOR ALL RETIREMENT ANNUITY CONTRACTS ISSUED ON OR AFTER JULY 1, 1941
(EXCLUDING CONTRACTS NUMBERED A900,000 TO A901,999 AND A970,000 TO A970,999)

As an owner of such a contract, you are hereby advised of a change in the Rate Schedule. The new Rate Schedule will replace the one now in effect on your contract and will take effect on January 1, 1986. It will be used from that date until it may be replaced to compute benefits purchased by: all premiums paid while it is in effect, any Additional Amounts credited while it is in effect, and all Transfers of funds from the College Retirement Equities Fund ("CREF") made while it is in effect. For all of such contracts issued from October 1, 1985 to December 31, 1985, Section 38 is amended so that this Rate Schedule will take effect on January 1, 1986.

RATE SCHEDULE

The benefits bought by premiums paid while this Rate Schedule is in effect will be computed on this basis:

(1) no deduction for expenses or contingencies;
(2) interest at the effective annual rate of 3% from the first day of the month in which the premium is paid to the Annuity Starting Date or your prior death, and at the effective annual rate of 2½% thereafter; and
(3) mortality according to the 1983 Table *a* (TIAA Merged Gender Mod A).

The benefits bought by Additional Amounts credited while this Rate Schedule is in effect will be computed on the same basis as for premiums.

The benefits bought by Transfers from CREF made while this Rate Schedule is in effect will be computed on the same basis as for premiums except that interest will be credited from the day TIAA receives the funds transferred.

When payments start to you, or to your beneficiary under an income method involving life contingencies, we will compute any benefits provided by the portion of the Accumulation resulting from premiums paid, Additional Amounts credited and Transfers from CREF made while this Rate Schedule is in effect on whichever of these bases produces the larger payments:

(1) the applicable interest rate and mortality tables, as stated above; or
(2) the interest rate and mortality table in use by TIAA for any individual single premium immediate annuities being offered when the payments start.

Amount of Yearly Life Annuity with 10-Year Guarantee Purchasable by a Single Premium of $100
One twelfth of the amount shown is payable each month

Age Attained When Premium is Due	Amount Beginning at			Age Attained When Premium is Due	Amount Beginning at			Age Attained When Premium is Due	Amount Beginning at		
	Age 60	Age 65	Age 70		Age 60	Age 65	Age 70		Age 60	Age 65	Age 70
20	$15.01	$19.17	$24.87	37	$ 9.08	$11.60	$15.05	54	$5.49	$7.01	$ 9.10
21	14.58	18.61	24.15	38	8.82	11.26	14.61	55	5.33	6.81	8.84
22	14.15	18.07	23.44	39	8.56	10.93	14.18	56	5.18	6.61	8.58
23	13.74	17.54	22.76	40	8.31	10.61	13.77	57	5.03	6.42	8.33
24	13.34	17.03	22.10	41	8.07	10.30	13.37	58	4.88	6.23	8.09
25	12.95	16.54	21.45	42	7.83	10.00	12.98	59	4.74	6.05	7.85
26	12.57	16.05	20.83	43	7.60	9.71	12.60	60	4.60	5.87	7.62
27	12.21	15.59	20.22	44	7.38	9.43	12.23	61		5.70	7.40
28	11.85	15.13	19.63	45	7.17	9.15	11.88	62		5.54	7.18
29	11.51	14.69	19.06	46	6.96	8.89	11.53	63		5.37	6.97
30	11.17	14.26	18.50	47	6.76	8.63	11.19	64		5.22	6.77
31	10.84	13.85	17.97	48	6.56	8.38	10.87	65		5.07	6.57
32	10.53	13.44	17.44	49	6.37	8.13	10.55	66			6.38
33	10.22	13.05	16.93	50	6.18	7.90	10.24	67			6.20
34	9.92	12.67	16.44	51	6.00	7.67	9.94	68			6.01
35	9.63	12.30	15.96	52	5.83	7.44	9.66	69			5.84
36	9.35	11.95	15.50	53	5.66	7.22	9.37	70			5.67

The yearly payments shown above are those that result from a premium of $100 paid or credited when you have reached an age shown in the "Age Attained" column, but have not passed that birthday by as much as one month. All ages used in computing benefits are calculated in completed years and months. Payments at ages other than those shown, and under other income methods are computed on the bases stated in the Rate Schedule for benefits bought by premiums. For premiums other than $100, payments will be proportionate.

Teachers Insurance and Annuity Association of America

James E. MacDonald
Chairman

— Attach This Schedule to Your Contract —

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TEACHERS INSURANCE AND ANNUITY ASSOCIATION
730 Third Avenue, New York, New York 10017

ENDORSEMENT ATTACHED TO CONTRACT

In accordance with the decisions of the United States District Court for the Southern District of New York, and the United States Court of Appeals for the Second Circuit in *Spirt* v. *TIAA-CREF and Long Island University*, 735 F.2d 23 (1984), *certiorari denied*, 53 U S L.W. 3269 (1984) when payments are being made under an Income Option or a Method of Payment of the Death Benefit: (1) TIAA will pay the Annuitant(s) either as a guarantee or as a guarantee plus Additional Amounts, a total benefit which shall be the higher of (a) the guaranteed payment under the applicable Rate Schedule or Schedules based upon the sex of the Annuitant and of the Second Annuitant, if any, and (b) the guaranteed payment under the applicable Rate Schedule or Schedules that would be made if the Annuitant and Second Annuitant, if any, were of the opposite sex, unless the earnings of TIAA for the prior calendar year fall below the level specified in the court decree; and (2) any further Additional Amounts credited shall be calculated under a formula which will bring the total payments, contractual plus Additional Amounts, to a level that does not vary by sex.

James G. MacDonald
Chairman

Attach this Endorsement to all Retirement Annuity Contracts issued from July 1, 1941 to December 31, 1985 inclusive, except those numbered A900,000 to A989,999 inclusive.

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ANNOUNCEMENT OF A NEW RATE SCHEDULE AND ENDORSEMENT FOR TIAA REGULAR, SUPPLEMENTAL, AND GROUP RETIREMENT ANNUITIES

As explained in an announcement sent to all TIAA-CREF participants in October 1984, a court mandate in the case of *Spirt v. TIAA-CREF and Long Island University* requires that all TIAA-CREF annuity income started on or after May 1, 1980 be paid on a sex-neutral basis. In addition to describing the general effects of the court order, the announcement noted that the court further requires TIAA to amend the annuity contracts and certificates of participants accumulating benefits. The enclosed new TIAA Rate Schedule, and the "Endorsement" on the back of the Schedule, are that amendment. If you have more than one TIAA annuity, you'll receive a copy of this amendment for each.

The new Rate Schedule determines how *contractually guaranteed benefits* bought by premiums, dividends, and transfers from CREF will be computed on January 1, 1986, and as long thereafter as the Schedule remains in effect. It will not alter the contractually guaranteed benefits already bought under prior Rate Schedules.

Since August 1, 1983, TIAA has been using a merged-gender (sex-neutral) mortality table to compute the guaranteed annuity benefits bought by

- premiums paid to TIAA on and after August 1, 1983,
- dividends ("Additional Amounts") resulting from these premiums, and
- CREF accumulations transferred to TIAA resulting from premiums paid to CREF on and after August 1, 1983.

The new Rate Schedule makes no changes in this respect; and the guaranteed amounts illustrated in it are the same as those in the Rate Schedule now in effect. It does prescribe, however, that as of January 1, 1986 the merged-gender mortality table will also be used to compute the *guaranteed* benefits bought by all TIAA dividends and CREF-to-TIAA transfers credited to your annuity on and after that date — *regardless of when the premiums that gave rise to these funds were paid.* The Schedule being replaced applies a sex-distinct mortality table to dividends resulting from TIAA premiums paid before August 1, 1983, as well as to CREF-to-TIAA transfers of accumulations resulting from premiums paid to CREF before that date.

DIVIDENDS ARE ADDED TO CONTRACTUALLY GUARANTEED BENEFITS

Dividends, declared primarily from TIAA earnings in excess of contractual requirements, increase the rate of interest credited during both the accumulation period and the annuity pay-out period. Dividends are currently declared for 12 months at a time, but they cannot of course be guaranteed for the future.

For accumulating annuities, dividends declared for the period March 1, 1985 through February 28, 1986 increase to 11¼% the total effective annual interest rate credited to accumulations resulting from premiums paid during this period. These dividends — the difference

(over)

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between the guaranteed interest rate and the total interest rate — are the "Additional Amounts" referred to in the Rate Schedule. Dividends added to your account purchase additional guaranteed benefits and in turn are credited with interest at the total effective annual rate.

For pay-out annuities, the 1985 dividend scale brings to 12% the effective interest rate at which total annuity payments, contractual plus dividend, are computed for the year. This dividend interest rate reflects not only current net earnings on the investments supporting pay-out annuities, but also the current mortality experience of TIAA annuitants and a gradual release of reserves built up during the accumulation period to protect the guarantees against unforeseen and adverse contingencies. To illustrate the effect of these dividends — for each $100 of monthly guaranteed income to an annuitant beginning income at age 65 under the Life Annuity with 10-Year Guaranteed Period, dividends increase the total monthly payment to about $255. Changes in the dividend scale for pay-out annuities have tended to be gradual and relatively small in any one year because of the long-term nature of TIAA's investments.

A NOTE ON CREF

CREF annuities make no dollar guarantees, and therefore CREF certificates have no Rate Schedules. CREF annuity income fluctuates annually in response to CREF's actual expense, mortality, and investment experience. CREF already conforms fully to all existing court decisions about the payment of sex-neutral annuity benefits.

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Mr. WALGREN. Thank you very much, both of you, for that testimony. I can see a number of young people in the audience who are interested in what is at stake in this operation.

I notice that so much of this, Mr. Peace, has come out of the military, and I think in many ways our society has underestimated that. It is my understanding that back in the fifties, it was essentially military funding in our system that really drove the initial computer development to begin with, and, so, we really have relied instinctively in our society on military research to accomplish a great deal of this.

We often wonder why everything has to be done under the military umbrella. It seems that every act in Congress is called the such and such security act. The energy development movement was done under the rubric of the National Energy Security Act. I wish we could find in our politics the support for recognizing what a national effort, has to contribute to an area, rather than require so much of our money to be spent in a military focus, even though the spinoff is as well.

Would you like to respond to that at all?

Mr. PEACE. I think from the national perspective, if you could increase the budgets for the National Bureau of Standards and the National Science Foundation, certainly the NASA budget is fairly reasonable but requires more, particularly I see great spinoff in the robotics and automation program for the space program, and for the U.S. economy. That was really pushed by the Congress.

But if you wanted to get away from the source of the major resources and research and development, historically, over the past decade or since World War II, there is only one way to do it, and that is to increase the budgets of these agencies, such as National Science Foundation and NBS, and you are not talking about $10 million, you are talking about $1 or $2 billion, if you want to solve a major national program that relates to the productivity improvement required by this country in the next 20 years.

But looking at one other aspect of the DOD Program, they are very mission oriented, and they are very technology driven. They have to solve these problems, and I guess the point of my testimony was that I begin to see a very—the trend toward the almost identical, very common technology base for both smart weapons, improved defense manufacturing as well as domestic manufacturing, and I think there is a need to direct the Department of Defense to pay more attention to economic development and to make sensible policy issues from the roles of mission's point of view.

Mr. WALGREN. Thank you.

Congressman Boehlert.

Mr. BOEHLERT. I would like to provide some comfort for you and all who are witnessing this hearing. I do wish to point out that in this tight budgetary period, the administration, this past budget year, requested significant increases for both NASA and the National Science Foundation. Unfortunately, it was not as enlightened as when we are dealing with the National Bureau of Standards, but the Congress worked its will and, so, we had some at least level funding during a period in which everything else was going down.

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Mr. Peace, you brought out something that the previous witnesses at this hearing have brought out, and I would like to reemphasize that when we are dealing with robotics and automation, we simply have no choice. We cannot stand still. We are getting clobbered in the international marketplace.

It is my understanding that we have operationally in the United States approximately 8,000 robots today. Whereas our friendly rivals across the Pacific in Japan have more than 100,000 operational robotics, and once again, we are getting clobbered in the international marketplace.

We have no choice but to proceed with the development, and this subcommittee, particularly, has been in the forefront of that and will continue to be.

Dr. Galbiati, I thank you for your statement, and I wish to assure you and all the witnesses that your entire statements will be made part of the record. The hearing will be documented and will be shared with all the members of the Science and Technology Committee.

But I like your innovative approaches, and I am intrigued with your technology application extension service concept. Do you think an institution like the college of technology might be able to handle something like that?

Dr. GALBIATI. Well, I think what is required here is not major funding at this point in time. I think what is required is a study to how best to apply this approach, that to go into and implement it is just not—as far as I can see, would be the wrong approach.

I think one ought to look at this thing and say is there any other possibility, and then look at some studies that will determine how this best should be put together.

Mr. BOEHLERT. Would you suggest that the Government do a university study?

Dr. GALBIATI. I think it ought to be at a university because the appropriate place probably is a university, as far as I can see, and it will come out of the universities in some place. It could be as you go into the study that you decide to do it a different way, but I think that the universities will give you a better chance in terms of being objective.

I will make the point that in terms of my data, what it shows also, is that the amount of activity in Canada, for example, the growth in there, is greater than it is in this country. I think if we are planning to extend this study to the international front, England and so forth, I think you would also find here that they are not standing still. That is why it is so critical that we move on this issue, but I think, again, the extension service—when we go out to small plants, they are afraid of automation, and they should not be.

Mr. WALGREN. If the gentleman would yield, I would like to just add one comment, and that is that in many ways, it seems to me what we have to invent are some new politics as well as some new technologies.

Traditionally in this country we have supported agriculture extension services, and it has not been controversial at all. It does not cause anybody to blink; and, yet, we are traditionally doing for that sector of the economy something which, politically, we refuse

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to do for another sector of the economy. If we are to find our way through this with some directness, we have to develop an appreciation of what it is we can do together; what the Government role really is; and in that sense, if we ought to be pursuing the kind of organization which goes out and brings knowledge of these capabilities to small industries as well as the large industries. We all would be better off for it.

Well, I do not mean to take any time, and I apologize. Let me call the next panel then. Dr. Robert Young, department of industrial engineering of Texas A&M University; and Dr. Richard Kenyan, the president, Association of Engineering Colleges of New York, who is also the dean of the college of engineering at Rochester Institute of Technology.

If you gentlemen would come forward. We appreciate your being here, and let me ask you to proceed in that order.

Dr. Young.

STATEMENT OF DR. ROBERT YOUNG, DEPARTMENT OF INDUSTRIAL ENGINEERING, TEXAS A&M UNIVERSITY, COLLEGE STATION, TX

Dr. YOUNG. I would like to thank you for having us here. I have prepared some charts that I would like to use to make a point that I am going to try to make.

The talk today is focused on automation and that generally is an implementation of the technology on the shop floor. What I am going to try to show you today is that I think the issue is broader than that, and that we really need to look at what goes on above the shop floor.

The chart that I have with me is from the Federal Reserve Board statistics and the Department of Labor. What you will see here is if we look at production output for the last 30 years, it's almost increased fourfold. It we look at the number of people involved in touch labor, for the last 30 years, it has remained relatively constant at about 20 million workers.

This seems like a contradiction because you have a tremendous increase in output and yet we are seeing a decrease in productivity, and we can see that this started about 1978, and it has been negative ever since, and we think this appears to be a contradiction. If we have a continual increase in output with the same number of people in touch labor, why are we having a decrease in productivity?

I think if we look at the cost distribution on manufactured goods, we can see that nontouch labor comprises approximately 70 percent of the costs, 70 percent of the costs of the manufactured goods, while touch labor comprises 20 to 30 percent.

So, we are seeing over twice the costs for labor is from indirect labor and not from touch labor. The conclusion we can draw there is that if all touch labor activities were automated, it is not going to significantly change the price or reduce the cost of manufacturing goods.

We have got to look at automation above the shop floor in addition to shop floor automation. Now, a question which may arise is what does non-touch labor do, and I would like to read a quote

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from John—Jim Lardner, director of management and operations for John Deere Corp. "The principal activity that most people engaged in manufacturing is creating, analyzing and transmitting and managing data while the actual material transformation is a secondary activity."

What he has said here is why I am showing you these statistics. The fact is that nontouch labor is primarily engaged in information processing activities. That is what they do.

Now, we talked about manufacturing, and I think that conjures up a picture in our minds of someone on the shop floor doing a machine operated job, running a press on a 4-day operation. Let us talk about that in terms of production. So, let us say what is manufacturing. It is the conversion of a design into a finished product. So, it includes planning, scheduling and getting whatever is necessary for the actual making of a product.

A shop floor automation can be addressed primarily through production or the actual making, and it is not looked at as manufacturing, which is the total system, and all those activities that support the actual making.

The conclusion we have, I think, is that the problem in manufacturing is one of managing information properly. Industry is trying to tackle this problem through the use of a computer, but the results have not been satisfactory. We have management information systems and decision support systems, but they tended to bury us in data while providing little information.

I know this may seem like a paradox, but it is really a dilemma, and we call it the information dilemma. Making lots of data and little information. As a result of the computer and the amount of information available for decisionmaking, that has accelerated in the last 30 years, but we have not seen a commensurate increase in the ability to convert the data into useful information and knowledge.

The Japanese have recognized this fact as the basis for their fifth generation computer project, similar recognition has created projects in England and in France. What they believe is that the key technology for solving the information dilemma is symbolic processing and not data processing. Symbolic processing is commonly known as artificial intelligence.

Although this can provide the solution technology, we must not forget that it alone cannot solve the problem. We have got to determine how to effectively apply the technology by building a manufacturing science base. We do not have a manufacturing science base in existence today. We know a great deal about the science of material transformation, but very little about the manufacturing systems.

Now, organized manufacturing has been producing products for nearly 200 years. So, we need to ask the question, why manufacturing science and the science base for it has not evolved, and I think the answer to this is that we have attempted to analyze the systems by examining isolated parts using tools borrowed from the physical sciences, and they are inappropriate for manufacturing systems.

Unlike a chunk of steel, a manufacturing system does not have consistent properties throughout. Consequently, studying a small

part in isolation provides no insight into the nature of the whole. We have a synergism associated with the manufacturing system such that the whole is more than the sum of the parts. This synergism is based upon the information relationship interconnecting all parts of the system.

The processing of information and its movement within these relationships forms the basis for the functions performed by indirect labor. In the history of modern-age manufacturing, there has only been two programs that have recognized the importance of information and the key elements responsible for synergisms of manufacturing and attempted to study them as a whole.

The ICAM Program out at the Air Force Materials Lab, and the AMRF Program at the National Bureau of Standards. The ICAM Program has been quite successful and this is the reason we have a great deal of computer integrated manufacturing in aerospace.

A problem with ICAM is that the dissemination restrictions precludes widespread distribution of the results. In addition, the program terminated this year. The automated manufacturing research facilities at the National Bureau of Standards is now the only U.S. program examining the manufacturing system as a whole from the information perspective, and it is severely underfunded.

It is ironic that we have many national laboratories funded with tens of millions of dollars per year and studying all sorts of esoteric things, and, yet, we cannot adequately fund a single facility to study a primary source of our Nation's economic well-being, that is manufacturing.

I believe that if we are to reverse the decline in productivity that has been prevalent during the past decade, we must set the following goals: We need to shift the focus of engineering away from the shop floor and toward the manufacturing system; we need to provide a means to study and experiment with the whole manufacturing system and not just its isolated parts; and maybe the most important thing, we need to recognize the single most important technology with which to improve productivity is artificial intelligence, and we must secure for this country unqualified leadership in development and application.

I think to achieve these goals, we need to increase support for the AMRF, either directly through the National Science Foundation or through the National Bureau of Standards, and to increase support for basic research in manufacturing systems and related artificial intelligence technology.

I think if we cannot achieve these goals, we are going to see our manufacturing base continually shift from a source of national pride to a source of national embarrassment.

Thank you.

[The prepared statement of Dr. Young follows:]

The Present and Future Impact of Automation on Productivity and the Future Focus of Engineering to Promote the Advancement of U.S. Industry

Testimony before the

U.S. House of Representatives'

Subcommittee on Science, Research and Technology

Robert E. Young

Industrial Automation Laboratory
Department of Industrial Engineering
Texas A&M University
College Station, Texas

October 7, 1985

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The principal activity of most people engaged in manufacturing is creating, analyzing, transmitting and managing data, while the actual material transformation is a secondary activity.

J.F. Lardner
Director of Manufacturing
John Deere Corporation

From Figure 1 we see that the growth of production output in the U.S. has increased over 300% during the last 30 years while the number of production workers has remained relatively constant at approximately 20 million. Today, the same number of production workers produce over three times as many manufactured goods as their counterparts in 1950. This phenomenal achievement is directly attributable to shop-floor automation. However, in contrast to this achievement is the fact that since 1979, our productivity growth rate has been negative (see Figure 2). Offsetting our technical achievements on the shop floor is an equally dramatic but even greater increase in the growth of non-production workers in manufacturing (see Figure 3). Non-production workers have increased from 16.5% to their present level of well over 34% of the manufacturing workforce. Consistent with this growth has been the growth of the manufacturing overhead rate from a level of 50% in 1955 to well over 100% today (Figure 4) with an increasingly upward rate of change (Figure 5). An examination of the cost distribution for manufactured products (see Figure 6) shows that indirect labor

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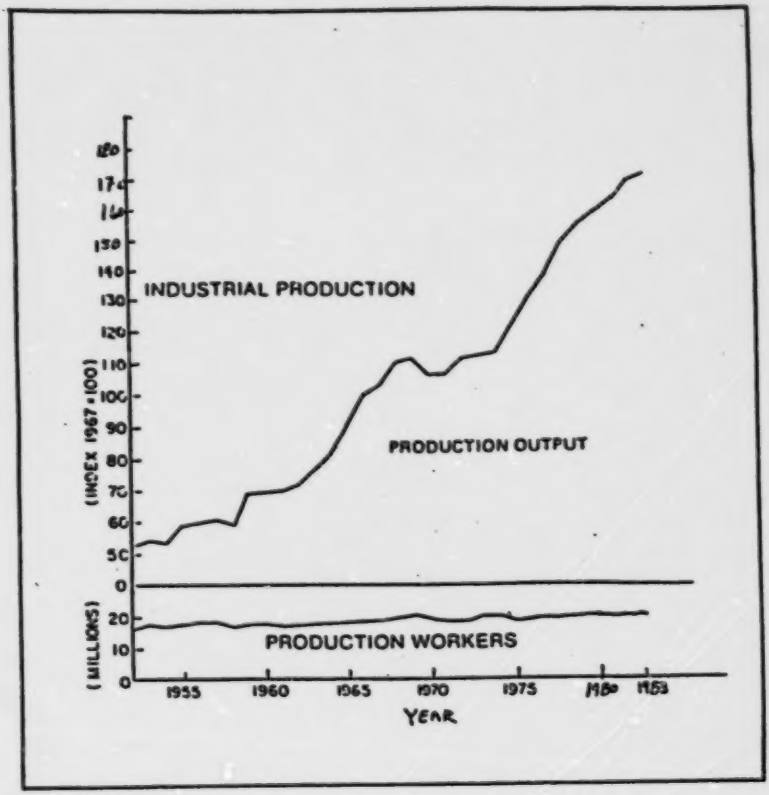

(Source: Federal Reserve Board statistics and U.S. Dept. of Labor Statistics)

Figure 1. The growth of production output versus the number of production workers.

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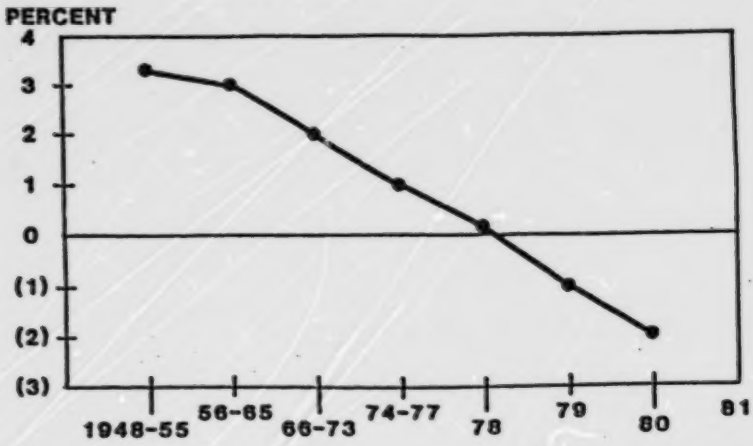

(Source: U.S. Department of Commerce)

Figure 2. Productivity growth rate in the U.S. (annual average).

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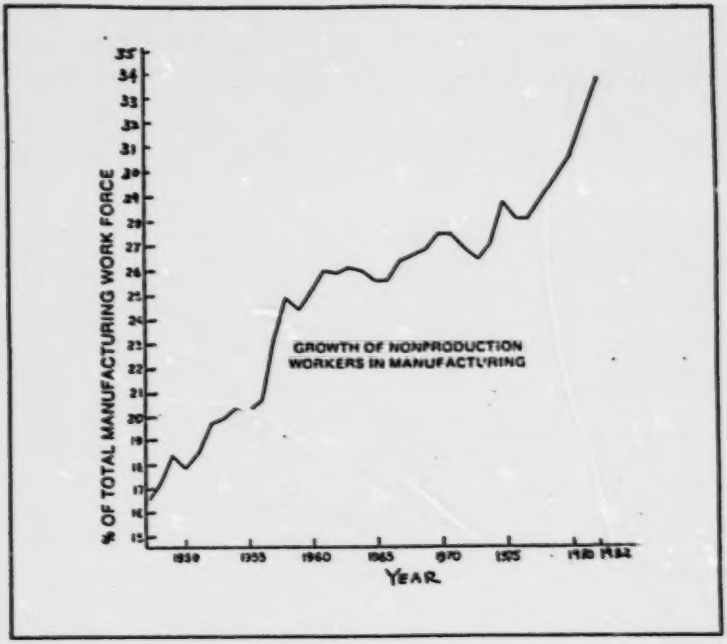

(Source: Bureau of Labor Statistics, U.S. Dept. of Labor)

Figure 3. Growth of nonproduction workers in manufacturing.

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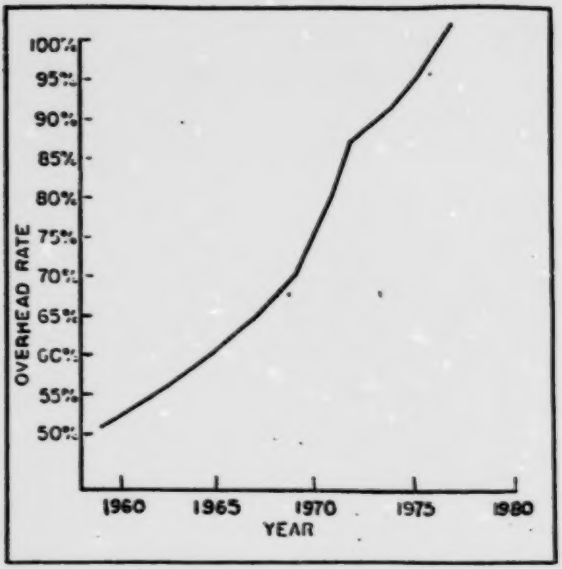

Figure 4. Manufacturing Overhead Growth Rate. (Source: Indirect Cost: A Productivity Issue for Manufacturing Technology, NC/CAM Journal, March-April 1980)

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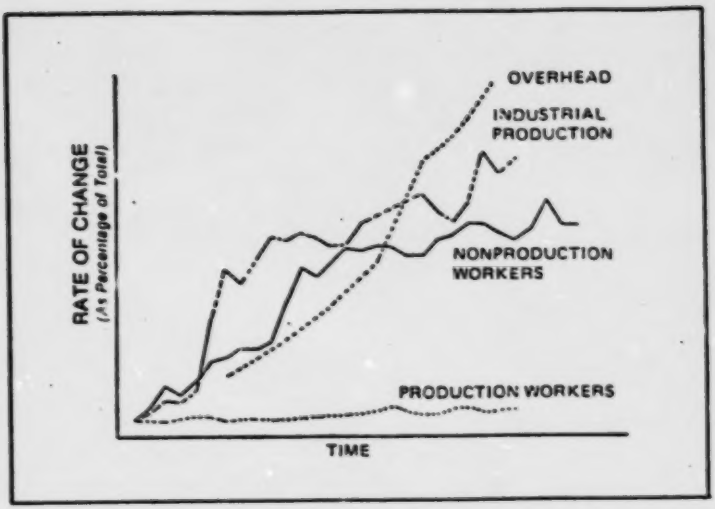

Figure 5. Rates of Change
(Source: Indirect Cost: A Productivity Issue for Manufacturing Technology, NC/CAM Journal, March-April 1980)

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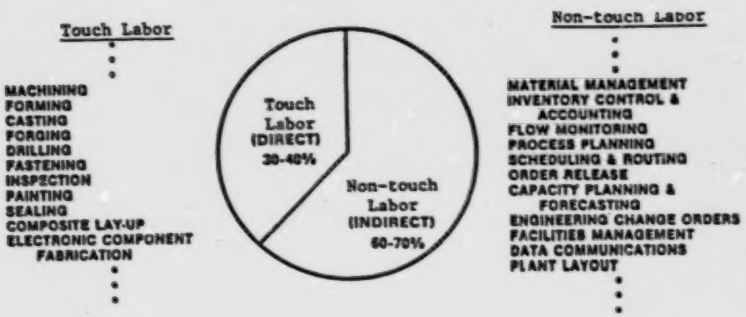

(Source: U.S. Air Force ICAM Program)

Figure 6. Cost distribution for batch manufactured products.

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may contribute twice as much to the manufacturing cost as direct labor.

From the data in Figures 1 through 6 we see that during the last 30 years, shop-floor automation has dramatically increased productivity, and that during the last ten years this increase has been more than been offset by rising indirect labor costs. This leads us to conclude that shop-floor automation by itself will not significantly reduce manufacturing costs.

To reduce the indirect costs we must first understand what constitutes manufacturing and what these costs represent. To achieve this understanding let us examine the following descriptions from the ICAM program at the USAF Materials Laboratory.

> ***Manufacturing*** *is the conversion of a design into a finished product. Manufacturing then includes planning, scheduling, and getting whatever necessary for the actual making of the product. ...**Production** is the actual making, the physical act of doing what is necessary to make the product. This includes altering the form of materials, assembling and testing. Consequently, production is a subset of manufacturing.*

Shopfloor automation in general has only attacked production, the actual making of a product; it has not attacked the other activities associated with manufacturing the product.

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Consequently, the current emphasis on automation and robotics at the shop floor level alone cannot significantly reduce the cost of manufactured goods.

As noted by Jim Lardner, the Director of Manufacturing for John Deere Corporation, the principal activity of most people in manufacturing is creating, analyzing, transmitting, and managing the information needed to support production. Consequently, the technology implementations most likely to make manufacturing more efficient are those which can make major improvements in the effectiveness of information creation and use.

Although industry has attempted to improve effectiveness through the use of the computer, the results have not been satisfactory. Management information systems, decision support systems, etc., have tended to bury us with data while providing little information. Although this may seem like a paradox, it is in fact an "information dilemma" currently facing manufacturing and business in general. The information dilemma is a result of the tremendous increase in the amount of data available for decision making without a commensurate increase in the ability to convert the data into useful information and knowledge.

This information dilemma is becoming more acute and is the major unsolved problem of the 80's. It is the basis for the

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Japanese Fifth Generation Computer Project and similar national efforts in Great Britain and France. It is their belief that the key technology for solving the information dilemma is symbolic processing and not data processing. Symbolic processing is commonly known as artificial intelligence. However, although artificial intelligence can provide the solution technology, it cannot alone solve the problem. We must determine how to effectively apply artificial intelligence by building a manufacturing science base.

The current science base in manufacturing is almost entirely focused in the production area. We know a great deal about the science of material transformation but very little about the manufacturing system. A recent Blue Ribbon Panel commissioned by a set of industrial researchers, academic researchers, and Dr. William Spurgeon of the National Science Foundation concluded in their report, "A Research Agenda for Models to Plan and Schedule Manufacturing Systems," the following:

> *Our assessment of past research and current practice reveals a disparity between the insights, orientation and methodologies of past research and possible scientific bases of current practice. Our conclusion is that there is a substantial need to focus research on the proper issues so that the next generation of practice has a scientific basis for each of the levels of planning.*

Since organized manufacturing has been mass producing products

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for nearly two hundred years, we must ask why a manufacturing science base has not evolved? The reasons lie in the nature and complexity of the system and with the tools available for analysis. We have attempted to analyze the system by examining isolated parts using tools borrowed from the physical sciences, and they are inappropriate for a manufacturing system. Unlike a chunk of steel, a manufacturing system does not have consistent properties throughout. Consequently, studying a small part in isolation provides no insight into the nature of the whole. There is a synergism associated with a manufacturing system such that the whole is more than the sum of the parts. This synergism is based upon the information relationships interconnecting all parts of the system. The processing of information and its movement within the relationships form the basis for the functions performed by indirect labor.

In the history of modern manufacturing there has only been two programs that have recognized the importance of information as the key element responsible for the synergism of manufacturing and attempted to study the system as a whole -- the ICAM program at the USAF Materials Laboratory and the AMRF program at the National Bureau of Standards. The Integrated Computer-Aided Manufacturing (ICAM) program was quite successful and is directly responsible for much of the computer-aided manufacturing activity in the aerospace industries. Unfortunately, the ICAM results have dissemination restrictions which preclude their wide distribution. In addition, the program was terminated last year.

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The Automated Manufacturing Research Facility (AMRF) at the National Bureau of Standards is now the only U.S. program examining the manufacturing system as a whole from an information perspective. Even though it is severely underfunded, the AMRF currently is the only facility available in the United States to study the complex integrated structure of manufacturing and experiment with new strategies. It is ironic that we have many national laboratories funded at tens of millions of dollars per year to study all sorts of esoteric things and yet we cannot adequately fund a single facility to study a primary source of our nation's economic well-being -- manufacturing.

If we are to reverse the decline in productivity prevalent during the past decade, we must set the following goals:

* To shift the focus of engineering technology away from the shop floor and toward the manufacturing system.

* To provide a means to study and experiment with the whole manufacturing system and not just its isolated parts.

* To recognize that the single most important technology with which to improve productivity is artificial intelligence and secure for the United States unqualified leadership in its development and application.

To achieve these goals the Federal Government needs to increase support for the AMRF either directly or through the National Science Foundation, and to increase support for basic research in manufacturing systems and related artificial intelligence technology. If we cannot achieve these goals, we will see our manufacturing base continue its shift from a source of national pride to a source of national embarrassment.

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STATEMENT OF DR. RICHARD KENYON, PRESIDENT, ASSOCIATION OF ENGINEERING, COLLEGES OF NEW YORK, DEAN, COLLEGE OF ENGINEERING, ROCHESTER INSTITUTE OF TECHNOLOGY, ROCHESTER, NY

Dr. KENYON. Thank you.

Good morning, and I very much appreciate the opportunity to be here this morning. I will keep my remarks brief.

My comments this morning derive from more than 30 years as an engineer and engineering educator. The views which I will express are my own, but they are shared by many in my profession.

The engineering education enterprise in New York State is second in size only to the system in the State of California. For many years, New York State has annually graduated the second highest number of engineers, baccalaureates, masters and doctorate level, and the State's enrollments comprise nearly 8 percent of the Nation's total engineering enrollment.

Because of the State's mix of large and small, public and private, rural and urban engineering schools, it is a cross section of the larger national picture and what happens in New York mirrors what is happening throughout the country.

The State engineering education system includes not only member schools of the Association of Engineering Colleges, those with accredited programs, but also a number of schools yet unaccredited, six institutions that offer the 4-year bachelor of technology degree, approximately six agricultural technical institutes that offer the associate degree in both engineering science and engineering technology, and additionally another 20 or so community colleges with a variety of 2-year programs in engineering science and engineering technology. All together, a rather awesome enterprise.

With nearly 30,000 undergraduate engineering students in the 4-year institutions alone, the physical plant of the collective institutions is operating at or at well beyond its designed capacity. Laboratories, many of which were outdated several years ago due to limited budgets, are now both overcrowded and approaching total obsolescence.

With approximately 1,200 full-time equivalent faculty, most schools are understaffed and new faculty in such areas as electrical and computer engineering, not to mention robotics and automation and manufacturing, are nearly impossible to hire. It has been estimated that the faculty shortage in New York State institutions may approach as much as 12 to 14 percent of the total authorized positions, and even if they were filled, the authorized positions would perhaps not be enough to meet the challenge. Personally, I am a little bit better off than some. With roughly 60 faculty; I am only 5 short as I begin the 1985-86 academic year.

There is not question that the U.S. manufacturing economy has suffered badly the past decade due, in part, to the higher quality and lower production costs of foreign competitors. It is ironic that much of the basic technology— automation, robotics, computerized engineering, computer manufacturing—was initially developed in this country, exported abroad, and ultimately used by our competition.

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Much of the theory and some of the technology was, in fact, developed in our colleges and universities, our schools of science and those of computer science and business. The need to include these newer technologies as part of the curriculum in engineering and technology has long been recognized by the educators, but their ability to bring substantial numbers of faculty up to speed in the new disciplines and simultaneously build and equip the needed laboratories has not been possible in a period of unprecedented enrollment growth, when even maintaining the basic curriculum has become such a challenge.

In spite of the difficulty of adding new programs, new faculty, and new laboratories to meet the challenge, some progress has been made. It may, however, be too little too late. Were it not for the assistance of American industry, substantially over the past 5 or 7 years, the engineering colleges and their technology counterparts would be in even worse shape than they are.

Let me give you an example not in the area of manufacturing, but in another of the fields where the United States is also being beaten by foreign competition, namely microelectronics. My own institution, Rochester Institute of Technology, undertook the establishment of this country's first baccalaureate program in microelectronic engineering 4 years ago, based on a 2-year-long market analysis of the United States in the semiconductor industry.

This past May, we graduated the Nation's first five B.S. microelectronic engineers. They were gobbled up very fast, I might add. The program has nearly 300 full-time students this fall. Later this year we will move into a new laboratory building containing over 10,000 square feet of clean room space for instruction in the fabrication of integrated circuits. The building will have cost $5½ million, only a small portion of which I have yet been able to raise. My neck is on the line with the trustees. It will contain over $4 million of fabrication and testing equipment.

That, I am happy to say, is in hand thanks to the very generous support of a broad base of semiconductor industries.

Having received it, I will now immediately have to start rolling it over because it becomes obsolete almost as quickly as I bring it in the door. I do not have enough faculty and few prospects for finding them, and the operating budget is awesome and the funds at hand woefully inadequate. We continue to push ahead, however, because these are the things that we must do.

This story with appropriate local variations could be recited by virtually every engineering dean in the country. Our colleges and universities have two basic problems that prevent them from adequately addressing the instructional needs of students and the research needs in such areas as manufacturing, robotics, electronics and the like.

First, is the lack of qualified faculty, and second is the lack of physical facilities and laboratory equipment. The faculty problem you have heard discussed here. I will not repeat it again. My story is simply a repetition of that.

Let me speak, however, to the matter of laboratories. To an extent, we are victims of our own success. Rapid pace of technological development has made our university laboratories increasingly obsolete. Worse yet, the new equipment we need to replace the old

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is more expensive to acquire, more expensive to operate, and more expensive to maintain, and ultimately, when we have to replace it, is more expensive again. It is increasingly difficult to do state-of-the-art research in university labs because of the equipment and the inadequate space.

There is clearly a need for computer hardware and software, robotics laboratories, advanced electronic facilities, and the like. However, there is equally a pressing need to refurbish the basic laboratories that undergird our engineering programs. As college after college cuts back in budgeting for these important facilities in the face of an overall decline in student population in this country, the research and instructional capabilities in engineering and technology programs is going down steadily.

So serious is the state of the undergraduate engineering laboratories in the colleges of New York State that the Association of Engineering Colleges is embarking this year on a major legislative program that will seek from the State funds in the amount of approximately $15 million over the next 5 years for the purpose of renovating those laboratories alone.

We are suggesting in our program that every State dollar should be matched equally by a dollar raised by the colleges and universities from business and industry. With current enrollment figures in the State, this amounts to only $200 per year per student, not an insignificant amount, but hardly a king's ransom. We are convinced that the economy of the State and the well-being of our industries demands no less from us.

Renovation and revitalization of the undergraduate laboratories should be the first element of what I hope will be an on-going partnership among the State governments, businesses, and industries in the State of New York and our engineering colleges.

The solution to the problems facing our engineering and technology institutions is the development of a partnership relationship with Government and business that views the colleges and universities not as objects of philanthropy, but as partners in economic redevelopment. Creative programs that will allow each to share the facilities, equipment, and personnel with one another will lead to the strengthening of all three. Most importantly, from my biased perspective as an educator, such a cooperative venture will make teaching and scholarship in the university environment once again an honored and sought after calling.

I thank you for the opportunity to make this presentation to you. I would be pleased to answer your questions.

[The prepared statement of Dr. Kenyon follows:]

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Testimony before the Subcommittee on Science, Research and Technology, Utica, New York, October 7, 1985

Dr. Richard A. Kenyon, P.E.
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716/475-2146

GOOD MORNING. MY NAME IS DR. RICHARD A. KENYON. I AM PROFESSOR OF MECHANICAL ENGINEERING AND DEAN OF THE COLLEGE OF ENGINEERING AT ROCHESTER INSTITUTE OF TECHNOLOGY, A POSITION THAT I HAVE HELD FOR THE PAST FIFTEEN YEARS. FOR THE PAST FIVE AND ONE HALF YEARS I HAVE SERVED AS THE PRESIDENT OF THE ASSOCIATION OF ENGINEERING COLLEGES OF NEW YORK STATE, A GROUP COMPRISING THE FOURTEEN PRIVATE AND SIX PUBLIC INSTITUTIONS IN THE STATE THAT OFFER ONE OR MORE ACCREDITED ENGINEERING CURRICULA PLUS THE TWO FEDERAL INSTITUTIONS LOCATED IN NEW YORK STATE THAT OFFER ACCREDITED ENGINEERING PROGRAMS, NAMELY THE U.S. MILITARY ACADEMY AT WEST POINT AND THE U.S. MERCHANT MARINE ACADEMY AT KINGS POINT. I AM A REGISTERED PROFESSIONAL ENGINEER IN THE STATE OF NEW YORK AND A MEMBER OF THE NEW YORK STATE BOARD FOR ENGINEERING AND LAND SURVEYING, HAVING BEEN APPOINTED TO THAT BOARD IN 1981 BY THE NEW YORK STATE BOARD OF REGENTS. I AM A FELLOW OF AND A MEMBER OF THE BOARD OF GOVERNORS OF THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS AND, ADDITIONALLY, A MEMBER OF THE NATIONAL SOCIETY OF PROFESSIONAL ENGINEERS, THE AMERICAN SOCIETY FOR ENGINEERING EDUCATION AND THE NATIONAL COUNCIL OF ENGINEERING EXAMINERS. FOR THE PAST SEVEN YEARS I HAVE ALSO SERVED AS AN AD HOC ACCREDITATION VISITOR FOR THE ACCREDITATION BOARD FOR ENGINEERING AND TECHNOLOGY, REPRESENTING THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. TWO YEARS AGO I SERVED AS A MEMBER OF ONE OF THE PANELS OF THE NATIONAL RESEARCH COUNCIL'S STUDY ON THE EDUCATION AND UTILZATION OF ENGINEERS.

MY COMMENTS THIS MORNING DERIVE FROM MORE THAN THIRTY YEARS AS AN ENGINEER AND ENGINEERING EDUCATOR. MY VIEWS DO NOT REPRESENT THE POSITIONS OF ANY OF THE ABOVE-NAMED GROUPS WITH WHICH I AM ASSOCIATED, SAVE THE COLLEGE OF ENGINEERING AT ROCHESTER INSTITUTE OF TECHNOLOGY AND THE ASSOCIATION OF ENGINEERING COLLEGES OF NEW YORK STATE, FOR WHICH ENTITIES I AM THE SPOKESMAN.

THE ENGINEERING EDUCATION ENTERPRISE IN NEW YORK STATE IS SECOND IN SIZE AND ANNUAL GRADUATES ONLY TO THE SYSTEM IN THE STATE OF CALIFORNIA. FOR MANY YEARS NEW YORK STATE HAS ANNUALLY GRADUATED THE SECOND HIGHEST NUMBER OF ENGINEERS AT THE BACCALAUREATE, MASTERS AND DOCTORAL LEVELS AND THE STATE'S ENROLLMENTS COMPRISE APPROXIMATELY EIGHT PERCENT OF THE NATION'S TOTAL ENGINEERING ENROLLMENT. BECAUSE OF THE STATE'S MIX OF LARGE AND SMALL, PUBLIC AND PRIVATE, AND RURAL AND URBAN ENGINEERING SCHOOLS IT IS A CROSS SECTION OF THE LARGER NATIONAL PICTURE. WHAT HAPPENS IN NEW YORK MIRRORS WHAT IS HAPPENING ACROSS THE COUNTRY. MY COMMENTS ARE

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LIMITED TO NEW YORK STATE BUT THEIR IMPACT SHOULD BE VIEWED AS NATIONAL.

THE STATE'S ENGINEERING EDUCATION SYSTEM INCLUDES NOT ONLY THE MEMBER SCHOOLS OF THE ASSOCIATION OF ENGINEERING COLLEGES BUT FOUR AS YET UNACCREDITED ENGINEERING SCHOOLS, SIX INSTITUTIONS THAT OFFER THE FOUR YEAR BACHELOR OF TECHNOLOGY DEGREE, APPROXIMATELY SIX AGRICULTURAL AND TECHNICAL INSTITUTES THAT OFFER BOTH THE A.S. DEGREE IN ENGINEERING SCIENCE AND THE A.A.S. DEGREE IN ENGINEERING TECHNOLOGY IN TWO YEAR PROGRAMS. ADDITIONALLY, THERE ARE ANOTHER TWENTY OR SO COMMUNITY COLLEGES THAT OFFER EITHER OR BOTH OF THE TWO ASSOCIATES DEGREE PROGRAMS IN ENGINEERING AND ENGINEERING TECHNOLOGY.

WITH NEARLY THIRTY THOUSAND UNDERGRADUATE ENGINEERING STUDENTS IN THE STATE, NOT COUNTING THOSE IN TWO YEAR PROGRAMS, THE PHYSICAL PLANT OF THE COLLECTIVE INSTITUTIONS IS OPERATING AT OR BEYOND CAPACITY. LABORATORIES, MANY OF WHICH WERE OUT OF DATE SEVERAL YEARS AGO DUE TO LIMITED BUDGETS, ARE NOW BOTH OVERCROWDED AND APPROACHING OBSOLESENCE. WITH APPROXIMATELY TWELVE HUNDRED FULL TIME EQUIVALENT FACULTY MOST SCHOOLS ARE UNDERSTAFFED AND NEW FACULTY IN SUCH AREAS AS ELECTRICAL AND COMPUTER ENGINEERING ARE NEARLY IMPOSSIBLE TO HIRE. IT HAS BEEN ESTIMATED THAT THE FACULTY SHORTAGE IN NEW YORK STATE INSTITUTIONS MAY APPROACH AS MUCH AS TWELVE TO FOURTEEN PERCENT OF THE TOTAL OF THE AUTHORIZED POSITIONS. I AM BETTER OFF THAN SOME. WITH ROUGHLY SIXTY APPROVED FACULTY POSITIONS I AM ONLY SHORT FIVE AS WE BEGIN THE 1985-86 ACADEMIC YEAR.

THERE IS LITTLE QUESTION THAT THE U.S. MANUFACTURING ECONOMY HAS SUFFERED BADLY IN THE PAST DECADE, DUE IN PART TO THE HIGHER QUALITY AND LOWER PRODUCTION COSTS OF FOREIGN COMPETITORS. IT IS IRONIC THAT MUCH OF THE BASIC TECHNOLOGY IN AUTOMATION, ROBOTICS AND COMPUTERIZED ENGINEERING AND MANUFACTURING WAS INITIALLY DEVELOPED IN THIS COUNTRY, EXPORTED ABROAD AND ULTIMATELY USED BY OUR COMPETITION. MUCH OF THE THEORY AND SOME OF THE TECHNOLOGY WAS, IN FACT, DEVELOPED IN OUR COLLEGES OF ENGINEERING AND OUR SCHOOLS OF SCIENCE, COMPUTER SCIENCE AND BUSINESS. THE NEED TO INCLUDE THESE NEWER TECHNOLOGIES AS A PART OF THE CURRICULUM IN ENGINEERING AND TECHNOLOGY HAS LONG BEEN RECOGNIZED BY THE EDUCATORS BUT THE ABILITY TO BRING SUBSTANTIAL NUMBERS OF FACULTY UP TO SPEED IN THE NEW DISCIPLINES AND TO SIMULTANEOUSLY BUILD AND EQUIP THE NEEDED LABORATORIES HAS NOT BEEN POSSIBLE IN A PERIOD OF UNPRECENDENTED ENROLLMENT GROWTH WHEN EVEN MAINTAINING THE BASIC CURRICULUM HAS BECOME SUCH A CHALLENGE. IN SPITE OF THE DIFFICULTY OF ADDING NEW PROGRAMS, NEW FACULTY AND NEW LABORATORIES TO MEET THE CHALLENGE OF A WHOLE NEW MANUFACTURING TECHNOLOGY AND PHILOSOPHY, SOME PROGRESS HAS BEEN MADE. IT MAY, HOWEVER, BE TOO LITTLE, TOO LATE. WERE IT NOT FOR THE ASSISTANCE OF AMERICAN INDUSTRY OVER THE PAST FIVE TO SEVEN YEARS, THE ENGINEERING COLLEGES AND THEIR TECHNOLOGY COUNTERPARTS WOULD BE IN EVEN WORSE SHAPE THAN THEY ARE. LET ME GIVE YOU AN EXAMPLE, NOT

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IN THE AREA OF MANUFACTURING BUT IN ANOTHER OF THE FIELDS WERE THE U.S. IS ALSO BEING BEATEN BY THE FOREIGN COMPETITION, NAMELY MICROELECTRONICS. MY INSTITUTION, ROCHESTER INSTITUTE OF TECHNOLOGY, UNDERTOOK THE ESTABLISHMENT OF THIS COUNTRY'S FIRST BACCALAUREATE PROGRAM IN MICROELECTRONIC ENGINEERING FOUR YEARS AGO BASED ON A TWO YEAR LONG MARKET ANALYSIS OF THE U.S. SEMICONDUCTOR INDUSTRY. THIS PAST MAY WE GRADUATED THE NATION'S FIRST FIVE BS DEGREE MICROELECTRONIC ENGINEERS IN A PROGRAM THAT THIS FALL HAS ALMOST THREE HUNDRED FULL TIME UNDERGRADUATE STUDENTS. LATER THIS YEAR WE WILL MOVE INTO A NEW LABORATORY BUILDING CONTAINING OVER 10,000 SQUARE FEET OF CLEANROOM SPACE FOR INSTRUCTION IN THE FABRICATION OF INTERGRATED CIRCUITS. THE BUILDING WILL HAVE COST FIVE AND A HALF MILLION DOLLARS AND WILL CONTAIN OVER FOUR MILLION DOLLARS IN FABRICATION AND TESTING EQUIPMENT. EXCEPT FOR MAYBE THREE QUARTERS OF THE CONSTRUCTION DOLLARS THAT I AM STILL WORKING ON, THE REST IS PRETTY MUCH IN HAND - THANKS ALMOST COMPLETELY TO THE SUPPORT OF THE SEMICONDUCTOR INDUSTRY. I STILL DO NOT HAVE ENOUGH FACULTY (AND FEW PROSPECTS FOR FINDING THEM) AND THE OPERATING BUDGET IS AWESOME AND THE FUNDS IN HAND WOEFULLY INADEQUATE. YET WE CONTINUE TO PUSH AHEAD BECAUSE THESE ARE THE TECHNOLOGIES OF TODAY AND TOMORROW AND THEY MUST BE AVAILABLE IN THE ENGINEERING CURRICULUM. THIS STORY, WITH APPROPRIATE LOCAL VARIATIONS COULD BE RECITED BY EVERY ENGINEERING DEAN IN THE COUNTRY.

THE STATE'S ENGINEERING COLLEGES AND UNIVERSITIES FACE TWO BASIC PROBLEMS THAT PREVENT US FROM ADEQUATELY ADDRESSING THE INSTRUCTIONAL NEEDS OF ENGINEERING STUDENTS AND THE RESEARCH NEEDS OF SOCIETY. FIRST IS THE LACK OF QUALIFIED FACULTY AND SECOND IS THE LACK OF PHYSICAL FACILITIES AND LABORATORY EQUIPMENT. PERMIT ME TO ADDRESS EACH BRIEFLY.

FIRST, THE FACULTY SHORTAGE. NATIVE BORN UNDERGRADUATE STUDENTS IN ENGINEERING (AND TO SOME DEGREE THOSE IN SCIENCE AS WELL) ARE STAYING AWAY FROM GRADUATE SCHOOL IN DROVES. THE PROFESSIONAL AND FINANCIAL REWARDS OF EMPLOYMENT IN INDUSTRY ARE TOO ATTRACTIVE TO MAKE GRADUATE SCHOOL (THE TRADITIONAL SOURCE OF NEW TEACHER/SCHOLARS) COMPETITIVE. SUBSEQUENT SERVICE AS FACULTY, FOR THOSE WHO DO PURSUE GRADUATE STUDY, IS SIMILARLY UNATTRACTIVE DUE TO NON-COMPETITIVE SALARIES, HIGH TEACHING LOADS AND INADEQUATELY EQUIPPED LABORATORIES. OUR GRADUATE SCHOOLS ARE IN LARGE MEASURE POPULATED BY FOREIGN BORN STUDENTS, MANY OF WHOM ARE NEITHER QUALIFIED NOR INTERESTED IN TEACHING. ONE INDUSTRIAL ENGINEERING DEPARTMENT HEAD HAS INDICATED THAT ANNUALLY THERE ARE ONLY ABOUT ONE HUNDRED NEW DOCTORAL GRADUATES IN THAT DISCIPLINE AND THAT PERHAPS ONLY TEN PERCENT ARE NATIVE BORN. THIS SMALL ANNUAL OUTPUT IS HARDLY SUFFICIENT TO MEET THE STAFFING NEEDS OF INDUSTRIAL ENGINEERING DEPARTMENTS IN ENGINEERING SCHOOLS AND THE RESEARCH AND DEVELOPMENT NEEDS OF INDUSTRY AND GOVERNMENT. SIMILAR CIRCUMSTANCES PREVAIL IN OTHER DISCIPLINES AS WELL. ALTHOUGH ENGINEERING AND COMPUTER SCIENCE FACULTY ARE ALREADY AMONG THE HIGHEST PAID ON MANY CAMPUSES, VACANT POSITIONS DO NOT APPEAR ATTRACTIVE TO THE LIMITED NUMBER OF QUALIFIED GRADUATES. IT IS ESSENTIAL THAT WAYS BE FOUND TO MAKE FACULTY SERVICE IN SUCH HIGH DEMAND AREAS AS ENGINEERING, COMPUTER SCIENCE AND TECHNOLOGY ATTRACTIVE TO THE BEST OF THE YOUNG MINDS IN THE COUNTRY. SALARY, MORE TIME FOR RESEARCH AND PROFESSIONAL STUDY AND BETTER EQUIPMENT ARE PART OF THE ANSWER. CHANNELING MORE

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BACCALAUREATE GRADUATES TOWARD GRADUATE SCHOOL IS ANOTHER PART OF THE ANSWER. BEFORE SUGGESTING AT LEAST ONE POSSIBLE ANSWER LET ME ADDRESS BRIEFLY THE MATTER OF LABORATORIES AND LABORATORY EQUIPMENT.

TO AN EXTENT, WE ARE VICTIMS OF OUR OWN SUCCESS. THE RAPID PACE OF TECHNOLOGICAL DEVELOPMENT HAS MADE OUR UNIVERSITY LABORATORIES INCREASINGLY OBSOLETE. WORSE YET, THE NEW EQUIPMENT WE NEED TO REPLACE THE OLD IS MORE EXPENSIVE TO ACQUIRE, MORE EXPENSIVE TO OPERATE, MORE EXPENSIVE TO MAINTAIN AND, ULTIMATELY, MORE EXPENSIVE AGAIN TO REPLACE. IT IS INCREASINGLY DIFFICULT TO DO STATE OF THE ART RESEARCH IN UNIVERSITY LABS BECAUSE OF THE OUTMODED EQUIPMENT AND INAPPROPRIATE SPACE. THERE IS CLEARLY A NEED FOR COMPUTER HARDWARE AND SOFTWARE, ROBOTICS LABORATORIES, AND ADVANCED ELECTRONIC FACILITIES. HOWEVER, THERE IS AN EQUALLY PRESSING NEED TO REFURBISH EVEN THE BASIC LABORATORIES FOR UNDERGRADUATE STUDENTS. AS COLLEGE AFTER COLLEGE CUTS BACK ITS BUDGETING FOR THESE IMPORTANT FACILITIES IN THE FACE OF AN OVERALL DECLINING STUDENT POPULATION IN THIS COUNTRY, THE RESEARCH AND INSTRUCTIONAL CAPABILITY OF THE ENGINEERING AND TECHNOLOGY PROGRAMS MOVES DOWN STEADILY.

LET ME CITE ONE PROGRAM THAT IS BEING UNDERTAKEN TO ADDRESS THIS CHALLENGE AND THEN I WILL CLOSE MY PREPARED REMARKS WITH A GENERALIZATION OF THAT IDEA.

SO SERIOUS IS THE STATE OF UNDERGRADUATE ENGINEERING LABORATORIES IN THE COLLEGES OF NEW YORK THAT THE ASSOCIATION OF ENGINEERING COLLEGES IS EMBARKING THIS YEAR ON A MAJOR LEGISLATIVE PROGRAM THAT WILL SEEK FROM THE STATE FUNDS IN THE AMOUNT OF FIFTEEN MILLION DOLLARS OVER THE NEXT FIVE YEARS FOR THIS PURPOSE ALONE. WE ARE SUGGESTING IN OUR PROGRAM THAT EVERY STATE DOLLAR SHOULD BE MATCHED EQUALLY BY A DOLLAR RAISED BY THE COLLEGES AND UNIVERSITIES FROM BUSINESS AND INDUSTRY. AT THE CURRENT ENROLLMENT LEVELS IN THE STATE THIS AMOUNTS TO ONLY TWO HUNDRED DOLLARS PER YEAR PER STUDENT - NOT AN INSIGNIFICANT AMOUNT BUT HARDLY A KING'S RANSOM. WE ARE CONVINCED THAT THE ECONOMY OF THE STATE AND THE WELLBEING OF OUR INDUSTRY DEMANDS NO LESS FROM US. RENOVATION AND REVITALIZATION OF THE UNDERGRADUATE LABORATORIES WILL BE BUT THE FIRST ELEMENT OF WHAT I HOPE TO BE AN ONGOING PARTNERSHIP AMONG THE STATE GOVERNMENT, THE BUSINESS AND INDUSTRY OF THE STAE OF NEW YORK AND THE ENGINEERING COLLEGES OF THIS STATE.

THE SOLUTION TO THE PROBLEM FACING OUR ENGINEERING AND TECHNOLOGY INSTITUTIONS IS THE DEVELOPMENT OF A PARTNERSHIP RELATIONSHIP WITH BOTH GOVERNMENT AND BUSINESS THAT VIEWS THE COLLEGES AND UNIVERSITIES, NOT AS OBJECTS OF PHILANTHROPY, BUT AS PARTNERS IN ECONOMIC REDEVELOPMENT. CREATIVE PROGRAMS THAT WILL ALLOW EACH TO SHARE FACILITIES, EQUIPMENT AND PERSONNEL WITH ONE ANOTHER WILL LEAD TO THE STRENGTHENING OF ALL THREE. MOST IMPORTANTLY, FROM MY BIASED PERSPECTIVE AS AN EDUCATOR, SUCH A COOPERATIVE VENTURE WILL MAKING TEACHING AND SCHOLARSHIP IN THE UNIVERSITY ENVIRONMENT ONCE AGAIN AN HONORED AND SOUGHT AFTER CALLING. I CANNOT IN FIFTEEN OR TWENTY MINUTES LAY OUT MORE DETAILED SUGGESTIONS, BUT I WOULD BE PLEASED TO ATTEMPT TO ANSWER YOUR QUESTIONS IF YOU WISH.

I THANK YOU FOR THE OPPORTUNITY TO SHARE MY CONCERNS AND HOPES WITH YOU.

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Mr. WALGREN. Thank you very much, Dr. Kenyon.

I think we really are running late, so I will withhold questions. I do want people to know that we will be working with these transcripts, so the fact that I do not ask some very pertinent questions now really does not mean that it has not all come to fruition.

So, I will withhold them and recognize Congressman Boehlert.

Mr. BOEHLERT. Well, the point I would like to emphasize is that I wish that the 395 Members of the House who are not members of the Science and Technology Committee could hear your testimony because, Dr. Young, as you know, we are strong supporters of the Bureau of Standards and the AMRF facilities. We have lost the supercomputer initiative, and, we have given the proper focus and emphasis to support for engineering from the National Science Foundation. Regarding instrumentation—we are moving in the right direction in terms of our committee, and it is our task to convince our colleagues that we need the support for these areas.

One question, Dr. Kenyon, if I may. How about the 2-year degree or the engineering technology degree? Is that something that we should encourage more of? Is there a marketplace for the skills? Are they being gobbled up by industry? How would you view that?

Dr. KENYON. The answer is that I think we should clearly encourage young people to look at all parts of that engineering technology, in fact, from the 2-year associate degree and the engineering technology to the Ph.D. in engineering.

Yes, they are being gobbled up at all levels. We do have a kind of a strange system in this country compared to many other countries, particularly European countries. We tend to have engineers who outnumber our technicians, our support staff, and, consequently, we occasionally find ourselves using the engineering talents for things that are somewhat wasteful.

We need to develop a much stronger cadre of technical support services for that engineering enterprise. So, yes, the 2-year institutions in both engineering and technology and the pre-engineering or engineering science are terribly important.

Without the engineering science programs in New York State, 20 schools would be unable to meet the demand from students, parents, industries, and society in general.

Mr. BOEHLERT. Thank you very much.

Mr. WALGREN. Let me add one comment to Dr. Young's testimony. In the graphs on the decline of productivity, one of the most interesting things is that the slope of the graph is uniform, even though we cross over into declining productivity in 1978. The slope of the decline has not changed since 1966.

Dr. YOUNG. That is correct.

Mr. WALGREN. So, whatever we are dealing with here, we are dealing with a uniform factor or trend that has been constant in our economy for the last 30 years.

Dr. YOUNG. I think that is true. Now, also, I was unable to pick up data beyond 1980. So, I do not know that it has. I know it has increased in terms of productivity, but I do not know the slope that it has accelerated or remained constant.

I did note, though, I was talking to a representative of an aerospace company this past week, who had some statistics, and the

contribution of touch labor in aerospace is about 10 percent of the product cost. The contribution of material is 55-percent.

So, what you are seeing is a tremendous cost factor coming from indirect labor. Three to four to five times that of direct labor.

Mr. WALGREN. And, that is a little different than the traditional thing that, oh, we have driven our labor costs so high that it is only foreign labor that we can compete with because you are really talking about touch labor when you are talking about the advantages of being offshore.

Dr. YOUNG. That is correct.

Mr. WALGREN. You are not processing too much information offshore.

Dr. YOUNG. Most of the—well, it is difficult to say. I do not know. So, I probably would be better if I did not comment. I do not know the management structure that exists when a company has offshore facilities. I do not know how their costs relate. The only thing I have information on is activities in this country.

Mr. BOEHLERT. Well, that would help to explain why we are preeminent in the world in terms of the aerospace industry, and why we are getting clobbered in terms of shoe manufacturing, for example.

Dr. YOUNG. I think so. I have some figures on Time Magazine this week, the wage gap. The average wage, hourly compensation for manufacturing workers in Brazil in terms of United States dollars is a $1.23 an hour. In the United States, it is $12.59.

Mr. BOEHLERT. Is that wages and fringes?

Dr. YOUNG. Yes. Now, I had a fellow visiting from Mainland China in my laboratory for several years. He was the vice chief of automation from the Wuxi Institute of Light Industry outside of Shanghai. He is the No. 2 man at this institute. He made $200 per month. That was his salary, and he told me that the skilled labor base on mainland China working in heavy manufacturing was making about 50 cents an hour.

So, I think that we are going to have—at those rates, it is difficult to see how complete automation at the shop floor level can compete with skilled labor making 50 cents an hour. I think we are going to have to look at the total system to try to reduce costs throughout the system, and I think the big area of opportunity is not the shop floor; we have been working on that for 30 years, and you can see the results have been phenomenal.

We really have not attacked—tried to automate the indirect sector, and I think that is because we have not been able to. I do not think it is out of neglect; it is out of frustration and failure that nothing has been done, but I think artificial intelligence gives us the tool to successfully reduce that cost.

But I think we have got to be able to identify what is going on in this system, and it is very difficult, if you just look at isolated aspects of it. We need a model plant, essentially, that we can study, and I think the first step in that direction is the automated manufacturing research facility.

Get one facility under one roof that we can go in and perturb and see what happens. It is very difficult to convince General Dynamics or General Motors that the change in operations, that you can see what it does to their system. They do not like to do that.

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Mr. BOEHLERT. The chairman and I recently visited AMRF, and we are fully supportive. You can look for additional support from this committee.

Thank you very much.

Mr. WALGREN. Thank you for your testimony which really focuses on the problem with such specificity.

Well, the last panel. Let me call on these representatives from industry: Dr. Mike Jefferies, from corporate research and development at General Electric; Dave Mitchell, who comes from Pittsburgh, PA, for which I have a special affinity, who is director of productivity and advanced manufacturing programs for Rockwell International; Dr. Philip Summers, the manufacturing research center, with IBM; and Edwin Harcourt, the vice president of product design engineering at Chicago Pneumatic Tool Corp., in Utica.

Well, gentlemen, we appreciate very much your coming and making these presentations to the committee. We have a half an hour to work with, so, let me ask you to give us your thoughts in the framework of 5 to 7 minutes. I apologize for the brevity but if we do that, we will be able to have a verbal presentation for the record, and then we will have your written statements for the details.

Let us go down the line in the order in which I introduced you. Dr. Mike Jefferies, first.

STATEMENT OF DR. MICHAEL JEFFERIES, CORPORATE RESEARCH AND DEVELOPMENT, GENERAL ELECTRIC, SCHENECTADY, NY

Dr. JEFFERIES. Thank you.

Good morning and thank you for the opportunity to testify on the subject of automation and robotics.

Of course, this subject is much too broad to discuss completely in a few minutes, so I will address just the part I know best from my perspective as an industrial R&D manager.

My testimony today will address the topics shown on page 2 of my hand-out material. First, I will give you a status report on industry's motivation to perform automation R&D. Next, I will refer to two concrete examples of automation R&D projects which show the nature of the work and provide illustrations for the next section where I discuss the role of the Government in automation R&D. Finally, I will review some of the problems facing universities' automation R&D and make some recommendations on Government action.

What motivates a company like GE to develop automation technology? Basically, as listed on page 3, there are two types of reasons; first, we recognize that automation is essential to the competitiveness of our manufacturing businesses, it reduces engineering and manufacturing costs, it reduces the time to bring new product concepts to market, and it enhances product quality by creating better designs and better controlled manufacturing processes.

We can often achieve these beneficial effects by adopting automation available on the market, but in some businesses, the best way to achieve competitive advantage is by developing our own unique automation technologies.

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The need for new technology is even more apparent in our businesses that offer automation products for external sale. Here, the market is highly competitive with both domestic and foreign firms battling for market share. Because of the factors I have just mentioned, GE, 5 years ago, announced a major thrust in automation, creating a new organization, acquiring several key firms, and investing large amounts in R&D.

Today, some 5 years later, we still believe that U.S. industry has only three choices: "automate, emigrate or evaporate." These words are more than just a catchy phrase, in GE, we believe them, and we think that much of U.S. industry believes them, too.

A growing number of firms know that automation is essential for survival. But compared to just 2 or 3 years ago, business conditions in manufacturing are so poor that many companies are not willing or able to make the investment needed to survive.

The outlook for automation is thus not nearly as good as it once was. The automation industry has the capability to develop the technology that the rest of U.S. industry needs, but the problem is business conditions. No Government action on R&D can effectively substitute for a revitalized manufacturing sector that will buy and use automation technology.

Let me now turn to some specific examples of automation R&D. I have singled out two areas on page 4 that I believe are especially important. First, the set of capabilities generally described as CAD/CAM/CAE, [computer aided design, computer aided manufacturing, and computer aided engineering] and, second, intelligent manufacturing processes made possible by today's computer technologies.

I will save a little time here by not discussing each of these subjects in detail, but both examples illustrate the type of automation R&D work which industry is well positioned to perform.

What then is the role of Government? This is addressed by the chart on page 8. One area where we believe Government should play a somewhat limited role is through R&D by Government laboratories. In general, we believe that Government laboratories are at a considerable disadvantage with respect to both industrial labs and universities. Government labs lack the close connection to commercial realities seen by industry, and they do not offer the unique atmosphere and side benefits of educating students associated with work at universities. So, as a general rule, we do not see Government labs as playing a major role in automation R&D.

But there are important exceptions. The first is in the area of automation standards; the sort of things that make it possible for one manufacturer's computer to talk to another's. In the CAD/CAM/CAE area that I referred to earlier, the transfer of data from the CAD system to the front end of the engineering analysis system was made easier by the existence of the Initial Graphic Exchange Specifications [IGES] developed by a joint effort between industry and the National Bureau of Standards.

Another exception is where Government labs have developed special capabilities. A case in point is the structural analysis code used to compute stresses in different objects, which originated at laboratories owned by the Department of Energy.

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In contrast to the limited role for Government laboratories, we see the participation of universities as essential. Their biggest contribution is in producing trained people. In fact, we have found that the availability of skilled people has been the limiting factor in our efforts over the last 3 years to build up programs in such critical areas as artificial intelligence, machine vision, and computer-aided design.

In fact, in computer-aided design, we have had to hire capable people with training in totally different areas—one had a Ph.D. in astrophysics, for example—and give them the time to learn a whole set of new concepts in order to proceed with our needed work.

Universities also have a long tradition of excellence in generating new technical ideas in both fundamental and applied research. Participation in industrial affiliate programs is one example of how industry has increased its support of universities in recent years. But, despite these increases, individual companies cannot justify supporting the full range of projects in a healthy university program. And, industry support creates problems concerning proprietary rights to the R&D results.

Thus, there is a clear role for Government here. In fact, in terms of direct action to support automation R&D, the most important role for Government, in my opinion, is to ensure the strength of universities, and such action is necessary because universities are facing significant problems in carrying out their role in automation R&D as listed on page 9 of the handout material.

These problems have been referred to this morning: funding and maintaining equipment required for much forefront automation R&D, maintaining an environment that attracts and holds the best people as faculty and also attracts good students, and carrying out work in technical subjects which require interdisciplinary teams with expertise beyond that which can be expected of any one professor.

What then should Government do? First, I would caution that there is much that is right with our universities, and poorly thought out actions might leave us worse off than we are now. In particular, it would be a mistake to provide funds for highly applied work which verges on product development, which is well handled by industry, to the detriment of work addressing fundamental understanding.

Rather, support should be targeted at the three problem areas I just mentioned. In this regard, we support several recent proposals which seem to address these issues, namely the recent initiatives to ensure that university faculty and students have access to the most advanced computer facilities, the Young Investigator Initiative that encourages talented young faculty to interact with industry, while providing them with resources to do forefront work, and the Engineering Research Centers that address the problem of programs aimed at the system area, requiring coordinated interdisciplinary solutions.

That concludes the remarks I have prepared.

Thank you for your attention, and I would be pleased to answer questions.

[The prepared statement of Dr. Jefferies follows:]

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Automation and Robotics — An Industrial R&D Perspective

M. J. Jefferies
Research and Development Manger, Engineering Physics Laboratories
General Electic Company, Corporate Research and Development
Schenectady, New York 12301

Testimony Before the U S. House of Representatives
Subcommittee on Science, Research and Technology,
Utica, New York, October 7, 1985

Good morning, and thank you for the opportunity to testify on the subject of Automation and Robotics. Of course, this subject is much too broad to discuss completely in 12 minutes, so I will address just the part of it that I know best. Specifically I will give you my perspective as an industrial R&D manager of about 350 people, most of whom are engaged in work aimed at advanced technologies for automation and productivity.

My testimony today will address the topics shown on page 2 of the handout material. First, I will give you a status report on industry's motivation to perform Automation R&D. Next, I will give two concrete examples of Automation R&D projects that show the nature of the work and provide illustrations for the next section where I discuss the role for government in Automation R&D. Finally, I will review some of the problems facing university automation R&D, and I make some recommendations on government actions.

What motivates a company like General Electric to develop automation technology? Basically, as listed on page 3, there are two types of reasons. First we recognize that automation is essential to the competitiveness of our manufacturing businesses -- it reduces engineering and manufacturing costs, -- it

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reduces the time to bring new product concepts to market, and -- it enhances product quality by creating better designs and better controlled manufacturing processes. We can often achieve these beneficial effects by adopting automation available on the market. But in some businesses the best way to achieve competitive advantage is by developing our own unique automation technology. The need for new technology is even more apparent in our businesses that offer automation products for external sale. Here the markets are highly competitive with both domestic and foreign firms battling for market share.

Because of the factors I just mentioned, GE five years ago announced a major thrust in Automation, creating a new organization, acquiring several key firms, and investing large amounts in R&D. Today, five years later, we still believe that U.S. industry has only three choices — "automate, emigrate or evaporate." These words are more than just a catchy phrase in General Electric -- we believe them and we think that much of U.S. industry believes them too. A growing number of firms know that automation is essential for survival. But, compared to just two or three years ago, business conditions in manufacturing are so poor that many companies are not willing or able to make the investment needed to survive.

The outlook for automation is thus not nearly as good as it once was. The automation industry has the capabilities to develop the technology that the rest of U.S. industry needs. But the problem is business conditions. No government actions on R&D can effectively substitute for a revitalized manufacturing sector that will buy and use automation technology.

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Let me now turn to some specific examples of Automation R&D. I have singled out two areas on page 4 that I believe are especially important: first, the set of capabilities generally described as CAD/CAM/CAE (computer-aided design, computer-aided manufacturing and computer-aided engineering), and second, Intelligent Manufacturing Processes made possible by today's computers.

Page 5 of the handout material shows a schematic view of the first area: CAD/CAM/CAE. This refers to the use of computers and interactive graphics to design, engineer and manufacture parts. The greatest impact today is in the area of Computer-Aided Design where CAD systems are used to conveniently generate and modify traditional blueprints. But in terms of the productivity enhancements that CAD/CAM/CAE technology offers, this is just the tip of the iceberg. Computer-aided engineering allows us to simulate and test design concepts with greatly reduced need for the expensive and time consuming process of making and testing working models. Computer-aided manufacturing allows us to generate the instructions for automatic machines more quickly and with fewer errors. But even the advances in the individual CAD, CAM, and CAE areas do not tell the whole story. Only by closely integrating the whole product cycle will we achieve a quantum leap in terms of shorter product introduction cycles, with higher quality and at lower cost than today's techniques allow.

An example of such an integrated cycle is shown on page 6. A computer representation of a part, in this case a plastic frame for a backpack, is made and portrayed as a shaded image at a graphics terminal, as shown at top left. The mathematical representation of the part is then passed through a number of computer analyses to determine if the design will work. In this case, regions of

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high stress that would result from a person standing on the frame are shown in red at the top right.

Once a satisfactory part geometry has been generated, the mold is then designed -- again entirely on the computer. Then we automatically generate machine tool paths. These paths are checked by simulating the machining process on a computer giving the result shown at the lower left. Since the part and its mold still exist only as electronic abstractions, we can even at this stage easily try design variations and check performance and manufacturability. Only after we arrive at an acceptable result, do we cut real metal to make the actual mold, shown at the lower right, and produce the part. The basic capability of going essentially automatically from "art to part" has been demonstrated. In my view it is inevitable that this technology will eventually be the standand way of producing a wide variety of products.

My second example is intelligent manufacturing based on machines that can sense what is happening, make decisions and adapt as needed to optimally perform their tasks. The particular case, shown on page 7, is an automatic system for Tungsten Inert Gas (TIG) welding. This system uses a visual sensor to automatically track irregular seams and maintain weld quality. The TV screen shows the image seen by the camera that looks right down through the torch. The bright lines are laser stripes; the breaks in the stripes mark where the seam is. Just off to the lower right of the brilliant arc you can see part of the weld puddle. Based on the shape of the puddle, the system adjusts the weld current and the torch speed to maintain the weld quality, adapting, for example, to changes in the seam width induced by heating of the parts during the welding process.

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The result is higher quality welds than can be achieved by human welders and with much higher productivity.

Both of these examples illustrate Automation R&D work which industry is well positioned to perform. What then is the role for government? This is addressed by the chart on page 8.

One area where Government should play a limited role is through R&D by government laboratories. In general we believe that govenment laboratories are at a considerable disadvantage with respect to both industrial laboratories and universities. Government labs lack the close connection to commercial realities seen by industry. And they do not offer the unique atmosphere and side benefits of educating students associated with work at universities. So, as a general rule we do not see government labs as playing a major role in Automation R&D.

But there are important exceptions. The first is in the area of automation standards, the sort of things that make it possible for one manufacturer's computer to talk to another's. In that CAD/CAM/CAE story I just told, the transfer of data from the CAD system to the front end of the engineering analysis system was made easier by the existence of the Initial Graphics Exchange Standard (IGES) being developed by a joint effort between industry and the National Bureau of Standards. Another exception is where government labs have developed special capabilities. A case in point is the structural analysis code used to compute stresses in the backpack frame, which originated at a laboratory owned by the Department of Energy.

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In contrast to the limited role for government laboratories, we see the participation of universities as essential. Their biggest contribution is in producing trained people. In fact we have found that the availability of skilled people has been the limiting factor in our efforts over the last three years to build up programs in such critical areas as Artificial Intelligence, Machine Vision, and Computer-Aided Design. In fact in Computer-Aided Design, we have had to hire capable people with training in totally different areas (one had a Ph.D. in Astrophysics) and give them the time to learn a whole set of new concepts in order to proceed with our needed work.

Universities also have a long tradition of excellence in generating new technical ideas in both fundamental and applied research. The through-the-torch welding vision concept used in our TIG system, for example, originated in work at a university where we were participants in an industrial affiliate program.

Participation in such programs is one example of how industry has increased its support of universities in recent years. But despite these increases, individual companies cannot justify supporting the full range of projects in a healthy university program. And industry support creates problems concerning proprietary rights to the R&D results. Thus there is a clear role for government here. In fact, in terms of direct actions to support Automation R&D, the most important role for government is to insure the strength of universities.

And such action is necessary because universities are facing significant problems in carrying out their role in Automation R&D, as listed on page 9 of the handout material. These problems are no doubt familiar to you:

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- funding and maintaining the equipment required for much forefront automation R&D
- maintaining an environment that attracts and holds the best people as faculty, and also attracts good students
- carrying out work in technical subjects which require interdisciplinary teams with expertise beyond that which can be expected of any one professor.

What then should government do? First I would caution that there is much that is right with our universities, and that poorly thought out actions might have leave us worse off than we are now. In particular, it would be a mistake to provide funds for highly applied work which verges on product development, which is well handled by industry, to the detriment of work addressing fundamental understanding. Rather support should be targeted at the three problem areas I just mentioned. In this regard we support several recent proposals which seem to address these issues, namely the recent initiatives to insure that university faculty and students have access to the most advanced computer facilties, the Young Investigator Initiative that encourages talented young faculty to interact with industry while providing them with resources to do forefront work, and the Engineering Research Centers that address the problem of programs aimed at system problems requiring coordinated interdisciplinary solutions.

Thank you for your attention. I would be pleased to try to answer any questions.

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Mr. WALGREN. Thank you very much, Dr. Jefferies.

Next, we will turn to Mr. Mitchell. Thank you for coming, Mr. Mitchell. We appreciate it.

STATEMENT OF MR. DAVE MITCHELL, DIRECTOR, PRODUCTIVITY AND ADVANCED MANUFACTURING PROGRAMS, ROCKWELL INTERNATIONAL, PITTSBURGH, PA

Mr. MITCHELL. Mr. Chairman, Congressman Boehlert, members of the committee. I am pleased to have this opportunity to tell you about the progress we are making at Rockwell in robotics and automation.

Certainly, the drive for improved productivity and quality are not new for Rockwell or American industry. We have all been trying for years to get greater productivity and quality in all our products.

Automation modernization has been one of these key strategies. We appreciate the opportunity to share with you a few of our activities in automation because we believe this is one route which U.S. industry can enhance its competitive position worldwide.

We have been investing aggressively for major programs new products, and especially for productivity and quality improvements. We spent over $3 billion for new facilities, equipment and systems since 1980. We estimate that about 66 percent of all these expenditures fall into the categories of cost reduction and automation.

For instance, we have moved aggressively in the development and implementation of CAD/CAM technology, spent well over $2 million for capital equipment, in this particular area. Our investment in software development that is unique for individual businesses is significantly higher than this.

Cad/CAM is currently being used by more than 95 percent of our operating divisions throughout the world, with very good results. We are investing about $500 million every year in computer hardware, software, office automation, local area networks, and telecommunications, to support engineering, manufacturing and information systems technology areas.

These investments have resulted in the ability to improve both our product design as well as our manufacturing processes. We are also involved in a number of modernization processes across many of our Government businesses.

Our Rocketdyne Division is currently working with NASA under a $10 million development program for advanced welding, using robotics. Rockwell is investing an additional $5 million for robotics equipment. This program uses advanced sensors for weld penetration and seam tracking and interactive graphics for off-line robotics programming.

At our strategic systems division in Anaheim, we have developed high precision robots to clean high tolerance gyro components for our missile guidance systems. These five access units cut time from 4½ hours to 14 minutes, with an improvement factor of 19. At the same time, they have also made significant improvements in quality.

We have experienced strong growth in the application of robotics in all our businesses. Many of our applications are in the more tra-

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ditional machine loading and unloading material handling areas with approximately 70 percent of our robotics applications being used for these applications.

A very good example of flexible automation at work is in a factory built by our Allen-Bradley subsidiary in Milwaukee, WI. This completely automated facility produces a world designed motor starter line of products, and that is, in itself, an interesting story of global competition.

Briefly, foreign starter manufacturers were beginning to sell in the U.S. market lower priced products. Allen-Bradley was responsible for strategic investment of about $15 million to design an automation showcase. It entered the market with a world product to be sold competitively in all markets. The plant capacity is about 600 starters per hour, many sizes and different variations; production is driven by orders, interdirecting in terminals at Allen-Bradley distributors worldwide, and sent directly to main frame computers in their headquarters in Milwaukee. Starting with raw materials, such as plastic, molding compounds, and metal stocks, plant makes just the number of controllers to meet the specific day's orders. Orders for receipts are shipped the following day, and necessary invoices are created as part of the process.

This new facility is a good learning experience, and it is truly a manufacturing system solution, and although it is fashionable to talk about manufacturing concepts of automation technology, in some cases, we realize pretty impressive productivity improvements with modest investments. With cellular manufacturing and improved production control systems and robotics, we have seen direct labor reduced by 50 to 60 percent, production rates increase by 100 to 200 percent, set up time reduced from 30 to 70 percent, major material moves reduced by 75 percent, and, in many cases, doubling up our inventory terms, and we have seen enormous improvements throughout.

A typical example, one of our manufacturing parts used to be in process for 54 days, shuttling around from one department to another. With cellular manufacturing, the whole process can now be accomplished in as little as 6 days. We have over a 175 manufacturing cells within our company, and many of these more traditional cells, we have added robots for additional flexibility.

We have recently brought on line one of our midwestern plants, a cell that turns out small iron valves. This cell utilizes robotics technology, produces one complete machine valve every 26 seconds. When we added a duplicate set of processes to the cell, it will put out a valve about every 15 seconds. Most efficient production for this type product in the world.

Automation acomplishes many things. Improves flexibility. Provides for the opportunity to rapidly respond to changing market demands. Increases quality. Provides a lower cost base. At the same time, it brings about a shift in technical skill level requirements for all employees.

At the operator and process plant levels, there is a distinct need for broader, multidisciplined skills. We are providing specialized training for literally thousands of our people, and we are now in the process of refining and sharpening this focus due to the tremendous need for training, new training techniques.

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We have learned that automation, modernization efforts, can only be successful through people initiatives, and we know that people make the greatest contribution to improved quality and productivity when they are involved in the process. Many companies have been successful in moving toward more work participation in decisionmaking at the plant level.

At Rockwell, we have several plants where we have planned for the integration of people and the technical systems long before the plants were built. These plants, located in both the United States and Great Britain, have their specific operating procedures and employee practices literally designed by employee teams. This cooperation that led to the successful new plant design processes has continued in day-to-day operations, resulting in factories that are not only productive but are great places to work.

These plants have achieved greater production levels, very high quality, extremely low level of absenteeism and employee turnover. Even though these plants are highly automated, they have some additional ingredients, such as all salaried work force, fewer levels of management, simplified job classification structures, and group incentive programs.

As we continue to automate our factories, we have not lost sight of the fact that we must do a better job, especially in the white collar areas. We are focusing considerable resources on this aspect of the business, just as we have done on the shop floor.

In conclusion, broader work skills among all our employees requires significantly broader levels of education and training. These new levels of automation mandate a more cohesive relationship between employees, machines, and technology. Education and training programs must consider new integrated social and technical environment requirements.

We have gained considerable experience and knowledge as a company and a Nation during the first half of the eighties with many of the emerging automation technologies. Now, we must make this all operational during the balance of the eighties to stay competitive in the global markets.

Is it worthwhile? We certainly think so. We are fully committed to strengthening our businesses through a balanced combination of innovative management and proven manufacturing strategies. This commitment is a key to our continued drive for manufacturing excellence.

We intend to be world class competitors in our areas of expertise. We believe the United States has the full potential to be world class competitors in this area of expertise also.

Mr. Chairman, again, it is a pleasure being offered the opportunity to testify here today. I would be pleased to respond to any questions.

[The prepared statement of Mr. Mitchell follows:]

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Statement of
J. David Mitchell
Director-Productivity & Advanced Manufacturing Programs
Rockwell International Corporation
Concerning

Robotics and Automation

Before The
Subcommittee on Science Research and Technology
of the
Committee on Science and Technology
United States House of Representatives

Utica, New York
October 7, 1985

Mr. Chairman and Members of the Subcommittee:

I am J. David Mitchell, Director - Productivity and Advanced Manufacturing Programs, on the corporate Operations staff of Rockwell International Corporation.

I am pleased to have this opportunity to tell you about the progress we are making at Rockwell in robotics and automation.

First, let me give you some idea of the scope of the company.

We expect our 1985 sales to be in excess of 11 billion dollars.

We have more than 120,000 employees. And a high percentage of them are engineers or hold other advanced technical degrees.

We have 5 major business operations and, under them, more than 40 divisions and other smaller business units.

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Our products include NASA's Space Shuttle orbiter, the B-1B aircraft, marine navigation systems, telecommunications, avionics, printing presses, truck axles and brakes, valves - meters and light vehicle components. Earlier this year we acquired Allen-Bradley, a leading manufacturer of industrial automation equipment and systems.

We operate in 285 locations on six continents.

Certainly, the drive for improved productivity and quality are not new for Rockwell, or American industry. We all have been trying for years to get greater productivity and quality.

Over the past several years, we have evolved at Rockwell a structured and disciplined methodology to insure that productivity and quality are integral parts of our business strategies.

Automation and modernization have been one of these key strategies and we appreciate this opportunity to share with you a few of our activities in automation because we believe this is one route by which U.S. industry can enhance its competitive position worldwide.

All of us recognize the strong contribution that capital makes to this improvement process and we have been investing aggressively for major programs, new products, and especially for productivity and quality improvements.

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We have spent over 3 billion dollars for new facilities, equipment and systems since 1980 -- and we estimate that about 66 percent of all these expenditures fall into the categories of cost reduction, automation and modernization.

Here are some areas of investment that deserve special mention.

For instance, we have moved aggressively in the development and implementation of CAD/CAM technology and have spent well over 200 million dollars for capital equipment throughout the company. Our investment in software development that is unique to our individual businesses is significantly higher than that.

CAD/CAM currently is being used by more than 95 percent of our operating divisions throughout the world -- with very good results.

In one case, major aircraft frame components were designed on a CAD system as full three-dimensional components. A frame was later selected to be converted to a forging by an outside vendor.

The 3-D database was electronically transmitted from Rockwell to the vendor where they were able to create the forging design, without drawings, directly from the 3-D database -- at significant savings in time and cost.

Rockwell is investing almost 500 million dollars every year in computer hardware/software, office automation, local area networks and telecommunications to support engineering, manufacturing and information system technology areas.

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We have also added a Cray super computer to our scientific computing resources in the last year. This 10-million-dollar computer will permit more effective payload, structural and thermal analysis on Space Shuttle, Space Station and B-1B, to name a few applications.

These investments have resulted in the ability to improve both our product design as well as our manufacturing processes. We are also involved in a number of modernization projects across many of our government businesses.

We are a firm believer in joint government/industry programs that provide modernization incentives and we are experiencing the advantages to be gained through them.

As an example, Rockwell has invested about 100 million dollars in a major facility at Palmdale, California, for final assembly and checkout of the B-1B's.

An important feature of this complex is a computerized checkout facility for the aircraft.

Four completed aircraft can be accommodated at one time, and up to 10 systems can be checked simultaneously.

The result is that B-1B systems can be checked out in about 4 weeks -- which compares with about 4 months using traditional methods.

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Here are examples of some other programs.

Within our Defense Electronics Business we have recently completed a state-of-the-art Gallium Arsenide (G_AA_s) facility in Newbury Park, California, for pilot production of very large scale integrated circuits under a DARPA contract. Rockwell has invested 14 million dollars in a facility which will manufacture the next generation, low-power, radiation-hardened chips that are capable of operating 5-to-10 times faster than current technology.

Our Rocketdyne Division is currently working with NASA under a 10 million-dollar development program for advanced TIG welding using robotics. Rockwell is investing an additional 5 million-dollars for equipment. The program uses advanced sensors for weld penetration and seam tracking and interactive graphics for off-line robotics programming. This welding modernization program will reduce costs and improve quality on Space Shuttle main engines and components.

At Autonetics Strategic Systems Division we have developed high-precision robots to clean high tolerance gyro components for inertial guidance systems. These five-axis units cut time from 4.5 hours to 14 minutes, an improvement factor of 19. At the same time they also made a significant improvement in quality.

We have experienced strong growth in the application of our robotics in all our businesses.

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We have gone from less than 10 units in 1979 to more than 150 units estimated for the fiscal year which just started.

Most of our applications are in the more traditional machine loading and unloading and material handling areas with approximately 70 percent of our robots being used for these applications.

A very good example of flexible automation at work is the "factory-in-a-factory" built by our Allen-Bradley subsidiary in Milwaukee, Wisconsin.

This completely automated facility produces a world design motor starter line of products and that in itself is an interesting story of global competition.

Briefly, foreign starter manufacturers were beginning to sell into the U.S. market with a lower priced product. Allen-Bradley's response was a strategic investment of about 15 million dollars to design an automation showcase and enter the market with a world product that could be sold competitively in all markets.

The plant capacity is 600 starters per hour. They come in two sizes and 125 variations and may be produced singly or in batches in any combinations.

Production is driven by orders entered on terminals at Allen-Bradley distributors worldwide and sent directly to a mainframe computer in Milwaukee.

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Starting with raw material such as plastic molding compound and metal stock, the plant makes just the number of controllers in the specific mix to meet that day's orders.

Orders received are shipped the following day and the necessary invoices are created as part of the shipping process.

And, although it's fashionable to talk about advanced manufacturing concepts and automation technology, in some cases we've also realized some pretty impressive productivity improvements with modest investments.

In many of our factories, we've simply rearranged our existing equipment and machinery to take full advantage of cellular manufacturing opportunities.

With cellular manufacturing and improved production control systems, we've seen direct labor reduced by 50 to 60 percent...

Production rates increased by 100 to 200 percent...

Set-up time cut by 30 to 70 percent...

Fork lift moves cut by 75 percent...

Inventory turns doubled...

And we've seen enormous improvements in throughput.

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In a typical example, one of our manufactured parts used to be in process for 34 days, shuttling around from one department to another.

With cellular manufacturing, the whole process now can be accomplished in as little as 6 days.

We currently have over 175 manufacturing cells in our company.

In many of these manufacturing cells we've added robots for additional flexibility.

We recently brought on line, at one of our mid-western plants, a cell that turns out small iron valves. This cell produces one completely machined valve body every 26 seconds.

When we add a duplicate set of processes to the cell, it will produce a valve body every 13 seconds — the most efficient production in the world for this type of valve.

Automation accomplishes many things: it improves flexibility, provides the opportunity to rapidly respond to changing market demands, increases quality, and provides a lower overall cost base.

At the same time it brings about a shift in the technical skill-level requirements for all employees.

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At the operator and process level there is a distinct need for broader multi-disciplined skills.

We are providing specialized training for literally thousands of our people and we are now in the process of refining and shaping the focus of our training techniques.

As an example, over 10,000 of our people have been trained in statistical process control techniques and these process control methods are being used by more than 70 of our plants.

We have learned that our automation and modernization efforts can only be successful through people initiatives, and we know that people make the greatest contributions to improved quality and performance when they are involved in the process.

Many companies have been very successful in moving toward more worker participation in decision making at the plant level.

At Rockwell we have several plants where we have planned for the integration of people and technical systems long before the plants were built.

These plants, located in both the U.S. and Great Britain, had their specific operating procedures and employee practices literally designed by employee teams.

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This cooperation that lead to the successful new plant design process has continued in day-to-day operation, resulting in factories that are not only productive but are great places to work.

These plants have achieved greater production levels, very high quality, and an extremely low level of absenteeism and employee turnover.

Even though these plants are highly automated they have some additional ingredients -- such as an all salaried workforce, fewer levels of management, simplified job classification structure, and group incentive programs.

As we continue to automate our factories, we have not lost sight of the fact that we must do a better job in the professional and white collar areas.

We are focusing considerable resources on this aspect of the business, just as we have done on the shop floor.

In conclusion, broader work skills among all our employees require significantly broader levels of education and training. These new levels of automation mandate a more cohesive relationship between employees, machines, and technology. Education and training programs must consider the new integrated socio-technical environment.

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Mr. WALGREN. Well, thank you very much, Mr. Mitchell. You know, Rockwell's shuttle has become the symbol of the future of the country, literally, and it is good to see that focused investment can work that kind of magic. We have a lot to learn from Rockwell and what you have done. So, we appreciate your being part of this record.

I need to apologize to the final two witnesses. Congressman Boehlert and I are going to have to remove ourselves. However, we will not remove our souls. I am sorry we will not get the chance to hear your testimony, but you can count on our giving it greater attention in its written form.

Because we have to leave to make a plane, we are going to leave behind the people who keep Washington going, and that is the staff of the committee, both the majority and the minority. Dr. Ezra Heitowit, who is here to my right, and Ms. Maryanne Bach, who is to my left, will stay and finish the discourse with you, and while I apologize for our having to leave, I think if you knew the inside story, you would not be disappointed at all in making your presentations to Dr. Heitowit and Ms. Bach.

So, with that——

Mr. BOEHLERT. Just let me add that the changed schedule of the House this afternoon comes about as the result of a meeting at 9 this morning. When we scheduled this meeting as late as Friday, we were assured that we would be OK, at least for another hour, but the last-minute change is completely beyond our control.

Second, I want to thank all the panelists, Dr. Cayan and the College of Technology for making this facility and your expertise available to us. Third, I would encourage all of you from industry to let Members of Congress know how important the Bureau of Standards is, how important the National Science Foundation programs are, how important the automated manufacturing research facility is.

We, because of our special responsibilities, are well tuned in, and we hear from you, but I would venture to say that the typical Member of Congress does not get one letter a year from back home, from industry, on how important the Bureau of Standards is.

Consequently, we get up on the floor during the period of austerity to fight for the dollars necessary to keep America competitive in the global marketplace and we sometimes are greeted with muffled yawns from people who do not understand the important mission of AMRF or the Bureau of Standards or NSF.

So, please, help us help you. Thank you very much. We will quietly excuse ourselves, and we will see you in Washington sometime. Please come by.

Dr. HEITOWIT. Our third witness is Dr. Phillip Summers of the Manufacturing Research Center, Research Division of IBM.

We welcome you, Dr. Summers.

STATEMENT OF DR. PHILLIP SUMMERS, MANUFACTURING RESEARCH CENTER, RESEARCH DIVISION, IBM, YORKTOWN HEIGHTS, NY

Dr. SUMMERS. Thank you.

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Good morning. I appreciate the invitation from the committee for having me appear here today. You have asked me to address and give my views on the following questions:

What is the role of automation and robotics in increasing U.S. productivity? What are the requirements on academia to produce the work force for the future?

I would like to begin with my view of the role that automation and robotics can play in increasing the productivity of U.S. manufacturing.

I interpret the potential of automation in the broadest possible way, which includes not only direct manufacturing activities, such as fabrication and assembly, things that normally take place in the shop floor, but also the automation of indirect functions, such as planning, design, administration, and management.

With gains in indirect productivity, we can have greater impact in those indirect areas. Also, the term robotics is far too narrow a word to describe the advanced auto machine tools of the future. The Japanese coined the word "mechatronics" to describe the application of mechanical and electronic engineering for the definition of advanced tools. Even this is too narrow a definition as it omits reference to the vital role that information and computers play in the effective application of these tools.

Future tools will have the ability to measure and adapt the variations of both product and process. Tools will be self-correcting in their operation and will monitor through key measurements the status of the product as it passes through the various stages of manufacturing, thus assuring higher quality products, more reliable manufacturing processes.

Robots, and other electronic tools, will not only act as a bridge between the information systems and physical actions needed to create tangible products, but will be creators and users of information.

For many high value products, such as those in the high technology and industries, future automated manufacturing systems will focus at least as much on the handling and processing, manufacturing and product related information, as they will on handling, processing of the product itself.

Direct linkages from the design systems to manufacturing systems will permit more rapid introduction of new product and flexibility to achieve a variety of product mix. Automation of production scheduling controls will permit the enterprise to respond to variations in product demand.

Automation applied in this general way will enable manufacturing enterprises of the future to produce higher quality products at lower costs and must be more competitive.

Let me now turn to the question of the role of education in preparing the work force to deploy and use new automation technology.

Underlying most of my earlier comments is my assumption that manufacturing of the future will have a very large technical component. I mentioned the importance of electrical engineering, mechanical engineering, information systems science. These will not be the only relevant disciplines for manufacturing.

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For example, as advanced products are developed, designed and introduced, they will incorporate advanced materials and with these will come the requirements for adequate understanding of the manufacturing properties and characteristics of these materials.

However, today, manufacturing is primarily an experience base rather than knowledge base activity. Many of the people who contribute to it either in the creation or the management or the execution of manufacturing processes learned their craft through experience, not through formal education.

Progress in manufacturing will depend on defining and developing a strong base of technical knowledge, skills that can be employed to create and operate these systems of the future. It has only been recently that academic disciplines have begun to focus on the problems of manufacturing. There is a tremendous need for increased educational activities at all levels from basic technical education to those carrying out manufacturing operations to programs for manufacturing related engineering, and, finally, to doctoral programs to prepare the faculty to carry out the research at advanced levels.

To be effective, ways must be found to facilitate the fine directional flow of information between the manufacturing community and educational institutions. Sponsored research programs should place an emphasis on technology transfer, such as the National Science Foundation engineering and research centers, that have the potential for encouraging information flow between these two communities.

There has been an increased interest in developing our manufacturing expertise through education in both industry and academia. IBM has encouraged the development of new programs for manufacturing systems engineering at a number of universities, and we reacted to our own needs for technical education by creating an institute for quality and for manufacturing technology.

A final observation: Today, manufacturing is not an activity that is held in sufficient high regard in this country. College graduates with degrees in finance and business are perceived as receiving greater respect and greater financial rewards. Our manufacturing future lies in attracting the best technical people to establish a strong technical base from which we can develop and apply the advanced manufacturing technologies that will enhance the U.S. competitive position in the future.

Thank you.

[The prepared statement of Dr. Summers follows:]

Testimony of Dr. Phillip D. Summers
To United States House of Representatives
Committee on Science and Technology
Subcommittee on Science, Research and Technology
Hearing at SUNY Marcy Campus, Utica, NY
October 7, 1985

Chairman Walgren, Congressman Boehlert, I appreciate your invitation to appear before you today.

You have asked me to address the following questions:

- What is the role of automation and robotics in increasing US productivity?
- What are the requirements on academia to produce the work force of the future?

I would like to begin with my view of the role that automation and robotics can play in increasing the productivity of US manufacturing.

ROLE OF AUTOMATION AND ROBOTICS:

I interpret the potential of automation in the broadest possible way to include not only direct manufacturing activities such as fabrication and assembly but also indirect functions such as planning, design, adminis-

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tration and management. The gains in indirect productivity can have greater impact than those in the direct areas.

Also, the term robotics is far too narrow a word to describe the advanced automation tools of the future. The Japanese have coined the word "mechatronics" to describe the application of mechanical and electronic engineering to the definition of advanced tools. Even this is too narrow a definition as it omits reference to the vital role that information and computers play in the effective application of these tools.

Future tools will have the ability to measure and adapt to variations in both the product and the process. Tools will be self corracting in their operation and will monitor, through key measurements, the status of the product as it passes through its various stages of manufacture thus assuring higher quality products and more reliable manufacturing processes. Robots and other mechatronic tools will not only act as the bridge between information systems and the physical actions needed to create tangible products but will be creators and users of information.

For many high value-add products future automated manufacturing systems will focus at least as much on the handling and processing of manufacturing and product related information as they will on the handling and processing of the physical product. Direct linkages from design systems to manufacturing systems will permit more rapid introduction of new products and the flexibility to achieve a variety of product mix. Autom-

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of the production scheduling and control will permit the enterprise to respond to variations in product demand.

Automation as applied in this general way will enable the manufacturing enterprise of the future to produce higher quality products at lower cost.

PREPARATION FOR THE FUTURE:

Let me now turn to the question of the role of education in preparing the work force to deploy and use the new automation technologies.

Underlying most of my earlier comments is my assumption that manufacturing of the future will have a large technical component. I mentioned the importance of electrical engineering, mechanical engineering and information and systems science. These will not be the only relevant disciplines for manufacturing. For example, advanced products will incorporate advanced materials and with these will come the requirement for adequate understanding of the manufacturing characteristics of the materials.

However, today, manufacturing is primarily an experienced based rather than knowledge based activity. Many of the people who contribute to ei-

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ther the creation or management or execution of manufacturing processes learned their craft through experience.

Progress in manufacturing will depend on defining and developing a strong base of technical knowledge and skills that can be deployed to create and operate the systems of the future. It has only been recently that academic disciplines have begun to focus on the problems of manufacturing. There is a tremendous need for increased educational activity at all levels, from basic technical education for those carrying out manufacturing operations; to programs for manufacturing related engineering and finally to doctoral programs to prepare faculty and carry out research at advanced levels.

To be effective, ways must be found to facilitate a bi-directional flow of information between the manufacturing community and educational institutions. Sponsored research programs that place an emphasis on technology transfer such as the National Science Foundation Engineering Research Centers have potential for encouraging information flow between these two communities.

There has been increased interest in developing our manufacturing expertise through education in both industry and academia. IBM has encouraged the developeent of new programs in Manufacturing Systems Engineering at a number of universities. In IBM we have reacted to our own need for technical education by creating Institutes for Quality and Manufacturing Technology.

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A final observation. Today, manufacturing is not an activity that is held in sufficiently high regard in this country. College graduates with degrees in finance and business are perceived as receiving greater respect and greater financial rewards. Our manufacturing future lies in attracting the best technical people to establish a strong technical base from which we can develop and apply the advanced manufacturing technologies that will enhance the US competitive position in the future.

Thank you.

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PHILLIP D. SUMMERS
Research Staff Member
Manufacturing Research Department
IBM Research
Yorktown Heights, NY

BIOGRAPHY

Dr. Summers is on the staff of the Manufacturing Research Department at the IBM Thomas J. Watson Research Center. He received the BS degree from the Massachusetts Institute of Technology in 1965, MS degrees from Syracuse and Yale Universities in 1971 and 1973 respectively, and the PhD in Computer Science from Yale University in 1975. He joined IBM in 1967 from The Boeing Company. While at IBM he has done research in automatic programming, computer languages for laboratory automation, and has served on the technical planning staff for the Director of Research. In 1977 he joined the Automation Research Group to do research in robot software and was co-designer of AML, IBM's robot language. In 1982 he became manager of a new research group, Automation Systems, consisting of projects directed at the systems aspects of programmable automation. He is currently on assignment to the Director of Manufacturing Research's technical staff.

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Dr. HEITOWIT. Thank you, Dr. Summers.

Our next and final witness on the panel is Mr. Edwin Harcourt, vice president of Product Design Engineering at the Chicago Pneumatic Tool Corp. here in Utica, NY.

Mr. Harcourt.

STATEMENT OF EDWIN L. HARCOURT, VICE PRESIDENT OF PRODUCT DESIGN ENGINEERING, CHICAGO PNEUMATIC TOOL CORP., UTICA, NY

Mr. HARCOURT. Members of the committee, preventing erosion of U.S. manufacturing world position and superiority is a complex problem. I would like to address my comments to the questions of productivity as a significant factor to U.S. manufacturing competitiveness in the world.

Major U.S. manufacturing companies have firmly established automation as a method to maximize productivity and product quality. They also have adopted robots as programmable tools to advance and improve automation processes.

Robots coupled with lasers are now performing machining and inspection functions, greatly improving accuracy and quality. For example, a truck plant in Michigan has planned for 1986 an unmanned body assembly section using 140 robots.

Flexible automation or flexible manufacturing systems is a means for companies with less continuous production throughput to be competitive worldwide. Computerized numerical control machining centers and robotics with capability for machine vision and other advanced technology are main ingredients for flexible manufacturing systems.

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Computer-aided design is widely used and must be expanded in smaller design companies. If used in conjunction with a flexible manufacturing system, a company's productivity can be substantially affected.

Our company has only scratched the surface, but we have achieved product development to production products in 1 year that had taken 3 years prior to the use of CAD and CNC machining centers.

Management and the work force needs to be made more knowledgeable and to improve technological skills. The entry engineer and engineering technician should be trained in these technologies and their application. Typical qualifications require computer software programming, microprocessor and laser technology, in addition to the basics.

Applied research should be balanced in the university with basic R&D; however, the near-term balance should be towards applied research to utilize U.S. industries' resources. Our company has a joint project currently with SUNY College of Technology on robotics with die grinders to deburr machining centers.

Government investment or government industry collaboration could be in the form of incentives to industry for both training and investment in automation technology. Industry working with the universities could then direct R&D focus on specific areas to advance productivity and world competitiveness.

Our company is directing future development towards improved productivity by application with automation, robots, and improved ergonomics to the users. The latter is by research on vibration and sound level reduction. These elements are of competitive significance in the world market.

It is reported manufacturing contributes 60 percent contribution to the U.S. economic wealth. Erosion of U.S. manufacturing has resulted from world competition by a combination of factors. Low labor rates productivity by government supported incentives for capital investment, low interest rates of capital, high dollar value for world equivalent monetary, and work ethic sponsored in part by government, industry, labor, academic cooperation.

Yes, continued government support in both applied and basic R&D to advanced flexible manufacturing systems, computerization and robotics is necessary.

Encouragement of industry/university collaboration is a must to raise industry's technology standards to regain our ability to compete in the world market.

That concludes my comments.

[The prepared statement of Mr. Harcourt follows:]

Statement of Edwin L. Harcourt, Vice President of Product Design Engineering, Chicago Pneumatic Tool Corp., Utica, NY

I would like to address my comments to the questions of "productivity" as a significant factor to U.S. manufacturing competitiveness in the world.

Major U.S. manufacturing companies have firmly established automation as a method to maximize productivity and product quality. They also have adopted robots as programmable tools to advance and improve automation processes. Robots coupled with lasers are now performing machining and inspection functions greatly improving accuracy and quality. For example, a truck plant in Michigan has planned for 1986 a unmanned body assembly section using 140 robots.

Flexible automation or flexible manufacturing system (FMS) is a means for companies with less continuous production through - put to be competitive world wide. Computerized numerical control (CNC) machining centers and robotics with cabability for "machine vision" and other advance technology are main ingredients for flexible manufacturing systems (FMS).

Computer aided design (CAD) is widely used but must be expanded in smaller design companies. Used in conjuction with a flexible manufacturing system a companies productivity can be substantially affected. Our company has only scratched the surface but we have achieved product development to production products in one year that has taken three years prior to the use of CAD and CNC machining centers.

Management and the work force needs to be made more knowledgable and to improve technological skills. The entry engineer and engineering technician should be trained in these technologies and their application. Typical qualifications requires software programming, microprocessor and laser technology in addition to the basics.

Applied research should be balanced in the university with basic R & D, however, the near term bias should be towards applied research to utilize U.S. indurtries resources.

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Edwin L. Harcourt

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BIOGRAPHY

Edwin L. Harcourt, V. P., Product Engineering, Chicago Pneumatic Tool Company, Tool Division, Utica, New York. Manufacturer of portable pneumatic, electric and hydraulic tools with manufacturing locations in Utica, New York; Detroit, Michigan; Nashville, Tennessee; India, Mexico and Japan. Have visited extensively manufacturers in Japan, Korea and Tiawan. Held various positions in engineering since 1951. Attended University of Michigan; member Society of Manufacturing Engineers and Robotics International; member ASME Standards Committee; Chairman, Pneumatic Tool Section, Compressed Air and Gas Institute.

Dr. HEITOWIT. Thank you, Mr. Harcourt.

We do have some time for some questions. I would like to start.

We have heard throughout the morning from many witnesses about the need to continue and increase the industry/university/Federal Government/local government collaboration in this area, partnerships.

I would like to ask each of the witnesses to give us their thoughts about what additional incentives or steps are required to increase both the number and magnitude of these partnerships. And, in particular, the industry/university collaboration that we are trying to enhance.

Do any of you have any suggestions, general or concrete, for us?

Mr. HARCOURT. A comment was made to increase the broad educational exposure to the work force, and any activity by industry and the university to do this is going to be beneficial.

Dr. JEFFERIES. I think that, Dr. Heitowit, the motivations for industry and university to work together already exist. I think in terms of what the government might do to encourage those relationships from my viewpoint would go back to the three items I mentioned earlier; the equipment needs, addressing the equipment needs of the universities, helping them retain good faculty and attracting good students, and then particularly the equipment needs that are coming about today because of the need to address system-type programs.

In a number of speeches this morning, they referred to CAD/CAM and so forth. Those areas require a great deal of equipment to pursue them realistically at universities.

Dr. SUMMERS. I think it is important that the universities be encouraged financially or otherwise to maintain their own identities in the areas of basic research. There is a great temptation to have cooperative arrangements between industries and universities where all the university gets and all that the knowledge base gets is the dollars to fund that particular activity.

Universities have a responsibility to be building a knowledge base for the future, and to be turning our disciplines having to do with manufacturing into something that can be taught and passed on to generation after generation, and, so, that to be able to do this, I believe, you need a strong sense of independence and substance away from simply the dollars that come in through the industrial sector.

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So, this is one role, I think, that is very important in supporting basic research.

Mr. MITCHELL. I think there is one other issue, I think, that industry seems to be—we talked a little bit today about our foreign competition. I think that there is a need for identity at the university level, certainly what Dr. Summers says, but it does appear like there is a tremendous duplication of effort. When the push in the United States started on productivity, it seemed like within 2 years or so, there was a productivity center that grew up at every university and every campus.

It seems like every university now has a robotic institutes or a robotics center. I am not saying that is bad, but I am saying if we study our competition, we do not compete head on head. They decide where they want to put their resources, and they are much more effective in both the learning process that maintains the faculty focus as well as how they interface with industry.

I think that is a lesson that U.S. industry interaction with the universities and university interaction with the Government could take as—I do not have the answer, but I do think that we kind of fall over ourselves trying to do what somebody else has done instead of trying to pick out the area of expertise and to really be good at that and to somehow share that for the benefit of industry so that, indeed, we are world class competitors in the market that we are in.

Dr. HEITOWIT. Well, these are very helpful suggestions.

Let me ask one timely question along these lines and that is, what do you see as the role of the extension of the R&D tax credit to corporations and the associated tax benefits deriving from gifts to universities, in collaboration with universities? Does that play a role in these partnerships?

Mr. HARCOURT. Certainly would help.

Dr. HEITOWIT. OK. Well, I will ask Ms. Bach if she has any questions.

Ms. BACH. I would just ask one question.

As we are trying to encourage the partnership between the university academia with industry and the role of the Federal Government, on the other side of the coin is a concern that too much information is flowing from American borders overseas in terms of the basic research funneling out, and to some extent, information is flowing from industry out. I wondered if you could comment on, from an industrial perspective, if it is really the flow of information abroad that is affecting our basic research and technology transfer into industry, or are there other factors that are really more prominent than the leakage of information from the United States?

Dr. SUMMERS. I would make one observation. There are two kinds of information that is generated usually in research. There is information having to do with science and basic understanding about the development of the world; and there is the second kind which has to do with the technology, and they have quite different characteristics, I believe.

Science, one wants to disseminate as widely and as quickly as possible, since that is the process of science, to disseminate the information, to have the feedback, and to let it develop in that way.

Technology is something that one usually tries to control. I am not sure how the international situation or the dissemination of information overseas, how that affects within our own corporation. We have our own policies that look at that. It is not something that I could really comment on.

Dr. JEFFERIES. I do not think I can add anything particularly profound, except to say that clearly one is looking for a kind of balance between the need to limit the flow of information and technology to unfriendly nations, but at the same time, there is a great strength derived from sharing basic and scientific information with peers and counterparts in other nations, and all I can offer there is, to some degree, we have got to find the right balance between the two.

Dr. HEITOWIT. I want to thank this last panel from industry very much, on behalf of the members and staff of this subcommittee. We are most grateful for all the witnesses appearing today and taking the time to prepare the testimony.

We may be back with additional questions in writing. We hope that that is agreeable, and we also wish to thank our hosts here at the State University of New York, College of Technology, for their hospitality and for giving us the use of these excellent facilities for holding this hearing this morning.

And, so, once again, thanks to all, and the hearing will be adjourned at this point.

[Whereupon, the subcommittee was adjourned.]

[Additional questions and answers for the record follow:]

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George M. Peace
Assistant to the President

1. What share of the resource burden required for automation should be assumed by the Federal Government and what share by private industry?

My opinion is that Federal Government/Industry support should be 60/40 percent respectively for the near term (next five years) and 40/60 percent respectively during the longer term. This distribution of resource burden is based more on intuition than facts--I suspect most replies to this question will be very subjective and recommendations for distribution based on individual biases. My personal bias is that the Federal Government should take the early initiative because of the critical nature of the manufacturing productivity problem.

A more rational answer to the question requires the study of information related to current status of resource distribution, national needs, national opportunities and the need for a national strategy associated with the assimilation of robotics/automation. In this regard, I suggest that the Congress commission the OTA to perform a study to provide the Subcommittee with the proper information to address the issue of resource allocation as well as other critical issues.

A study methodology as reflected in Figure 1 might be considered. The key ingredient of the study would be a determination of the need for a national strategy, the establishment of near term and long term goals associated with resource distribution and specific programs to achieve the goals.

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2. Could you elaborate on the process whereby "spin-off" companies evolved from ERIM?

The transfer of Federally sponsored R&D to the private sector via the ERIM organization occurs by three mechanisms: 1) the creation of spin-off companies, 2) contract research with private sector companies wherein specialized R&D is applied to private sector problems, and 3) the transfer of technology to the defense industry through DoD mechanisms.

For the most part these mechanisms work as a result of the character of ERIM as a non profit research institute and its ability to work effectively with a wide variety of public and private organizations while developing novel ideas to solve a sponsor's problem. At an elementary level research institutes attempt to solve problems for their customers; however, in practice, institutes often pool the interests of many sponsors to structure complex research programs that deliver as much as possible to all interested parties. That is, some leverage is achieved by integrating the interests of many sponsors.

For example, ERIM conducts an integrated program to advance the state-of-the-art in sensor technology in response to the needs of DoD, NASA, and other sponsors. Additional leverage is achieved through the process of technology transfer, especially the transfer of space and defense technologies for application to domestic problems. The key factor here is that a research institute may work with widely separated segments of society, e.g., biologists and defense analysts. Great strides have resulted from transferring techniques in one area to another seemingly unrelated area, and the scope of diverse activities brought together in a research institute is both aimed at and a result of the technology transfer process.

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Spin-Off Companies

The process whereby "spin-off" companies evolved from ERIM, historically, has not been part of a planned program. "Spin-offs" occurred as engineers, during the course of performing contract research, developed new ideas, learned business skills through contract management and developed marketing skills via customer interface. Those engineers that developed these entrepreneurial skills often left the Institute to form a new enterprise. Some would-be entrepreneurs did not succeed and returned to work at the Institute; some of these tried later and succeeded.

The Institute does not stress production or commercialization. Thus, difficulties commonly associated with spin-offs from large corporations (conflicts associated with trade secrets, patents, etc.) are minimized.

In short, the spin out process can be related to the hi-tech atmosphere created at ERIM and the corresponding willingness to let would-be entrepreneurs leave with innovative technology without the usual conflicts associated with profit oriented companies.

In recent years ERIM has experimented with ideas to develop a more formal approach to spin-off companies with the intent to create future endowments for the Institute.

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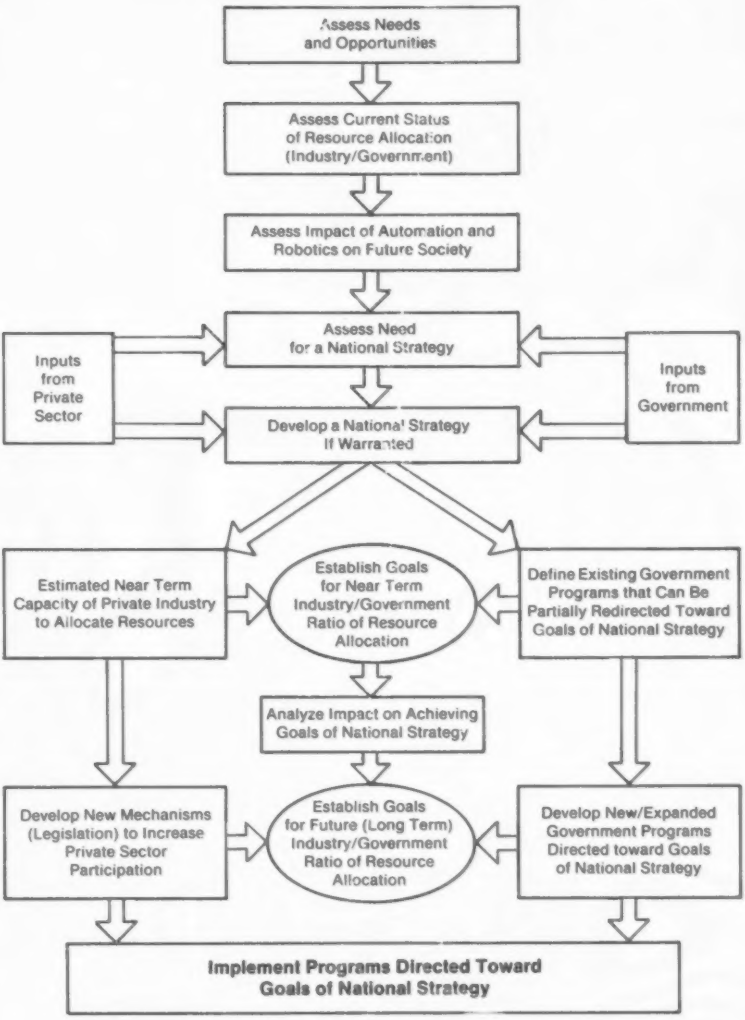
THE ROLE OF AUTOMATION AND ROBOTICS IN ADVANCING U.S. COMPETIVENESS: INDUSTRY/GOVERNMENT PARTICIPATION


Assess Needs and Opportunities
Assess Current Status of Resource Allocation (Industry/Government)
Assess Impact of Automation and Robotics on Future Society
Assess Need for a National Strategy
Inputs from Private Sector
Inputs from Government
Develop a National Strategy If Warranted
Estimated Near Term Capacity of Private Industry to Allocate Resources
Establish Goals for Near Term Industry/Government Ratio of Resource Allocation
Define Existing Government Programs that Can Be Partially Redirected Toward Goals of National Strategy
Analyze Impact on Achieving Goals of National Strategy
Develop New Mechanisms (Legislation) to Increase Private Sector Participation
Establish Goals for Future (Long Term) Industry/Government Ratio of Resource Allocation
Develop New/Expanded Government Programs Directed toward Goals of National Strategy
Implement Programs Directed Toward Goals of National Strategy

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